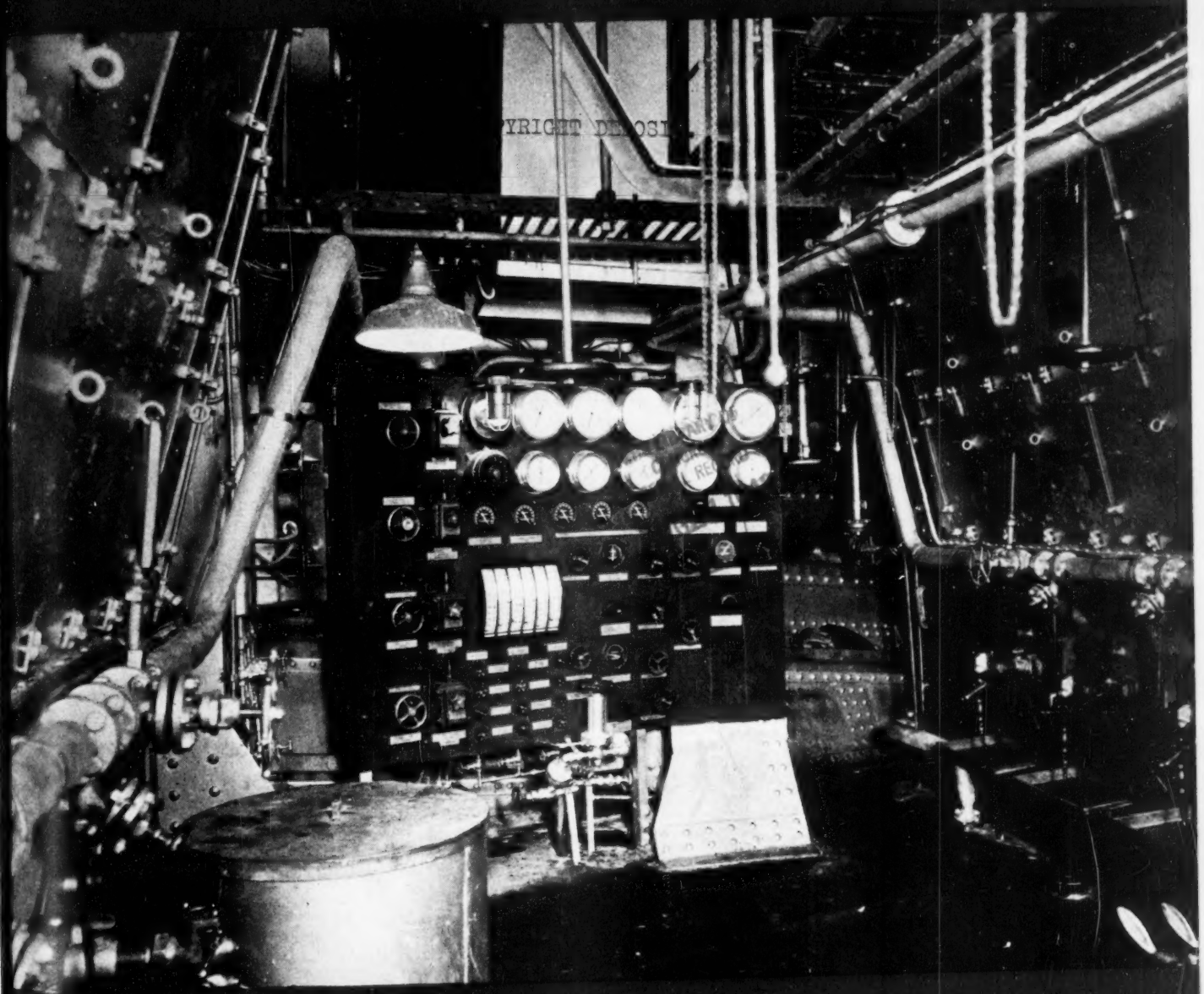
# Instruments

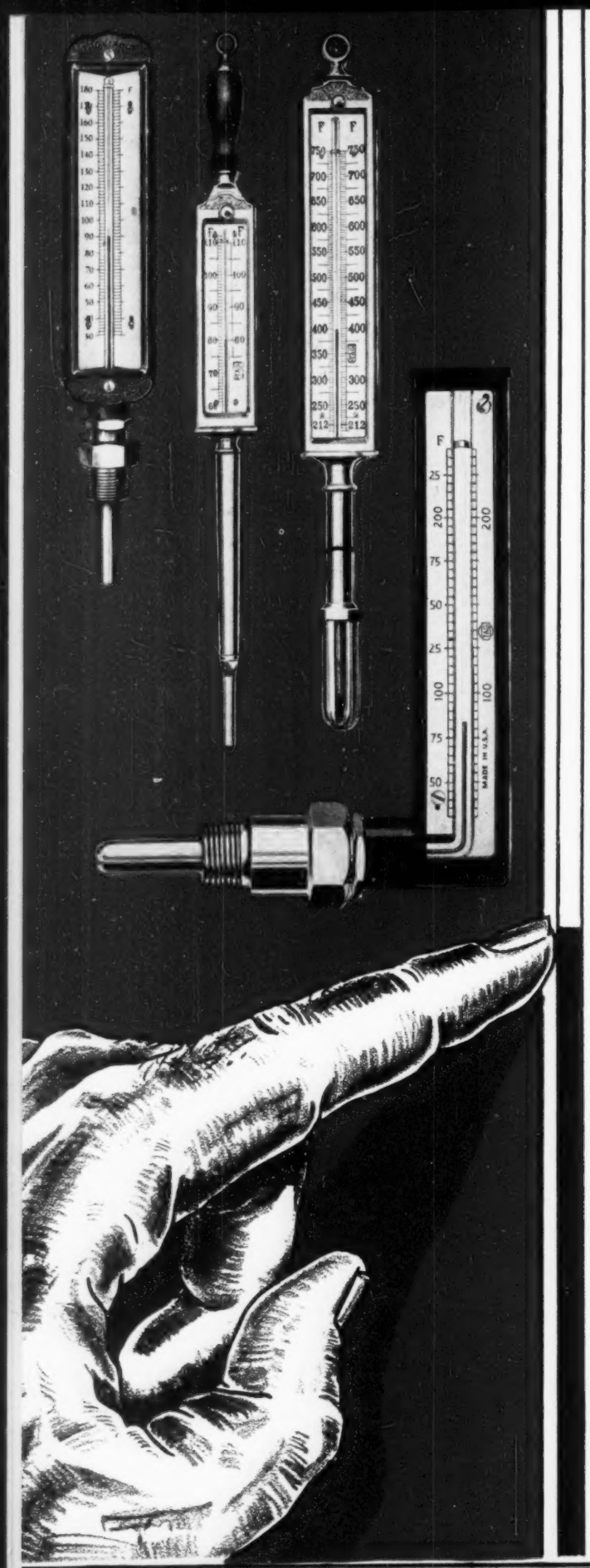
THE MAGAZINE OF

# Measurement and Control

Vol. 16
AUG.
1943
No. 8



INCLUDING *Aviation Instruments*



# Precise Intelligence

## A PRIMARY CONSIDERATION IN ALL OPERATIONS INVOLVING THERMOMETERS AND MEASUREMENTS OF TEMPERATURE

But, high accuracy alone is not enough. Simplicity of design in non-critical materials and the ruggedness to stand the terrific shocks of battle conditions on shipboard—the rough usage encountered in a hundred war industries—these, also are important.

TAG has met all of these demands in many ingenious ways. Lightweight plastic replaces heavy brass for case fronts—malleable iron and zinc alloys instead of brass and aluminum for cases—durable, attractive finishes which employ neither nickel nor chromium alloys.

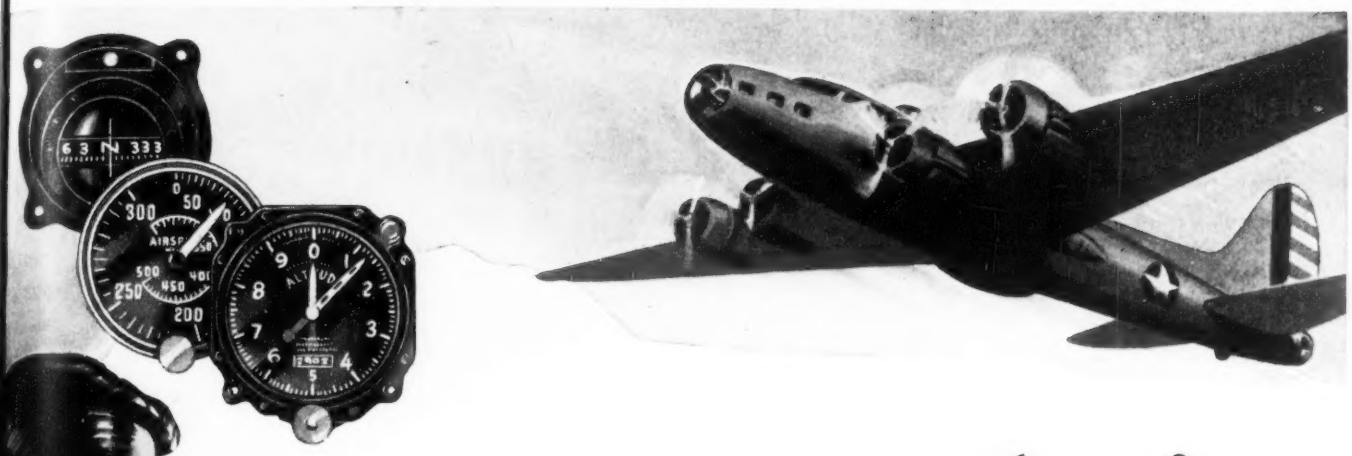
Tens of thousands of TAG Thermometers are contributing precise temperature intelligence in all war theaters and across the vital production front. Every type of vessel sailing the seven seas . . . Submarines, Destroyer Escorts, Aircraft Carriers, Cruisers and Battleships find TAG equipment on Diesels, turbines, in boiler rooms, on refrigerating systems, propulsion machinery and in many other applications. And in the manufacture of high-octane gasoline, synthetic rubber, explosives, varnish and in the processing of vital foodstuffs TAG Thermometers are much in evidence.

TAG is doing a big job well in this war just as it did in the last and America's previous wars for over a hundred years.

**C. J. TAGLIABUE MFG. CO.**

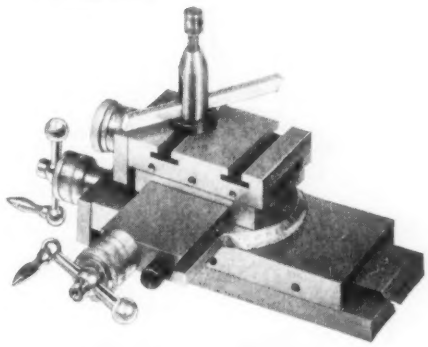
**Park & Nostrand Ave's., Brooklyn, N. Y.**

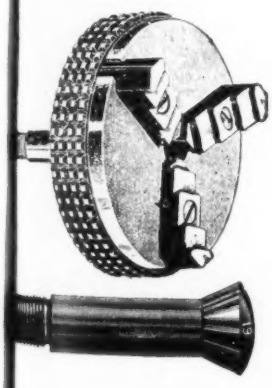
TAG



# Another Plane Returns Safely

**PRECISION TOOLS** play a vital role in safeguarding the lives of our pilots. Their instruments MUST perform under all conditions — they MUST NOT fail. The success of their mission — the safe return of the ship and crew — these things depend upon the accuracy of the instruments and the tools that repair them.





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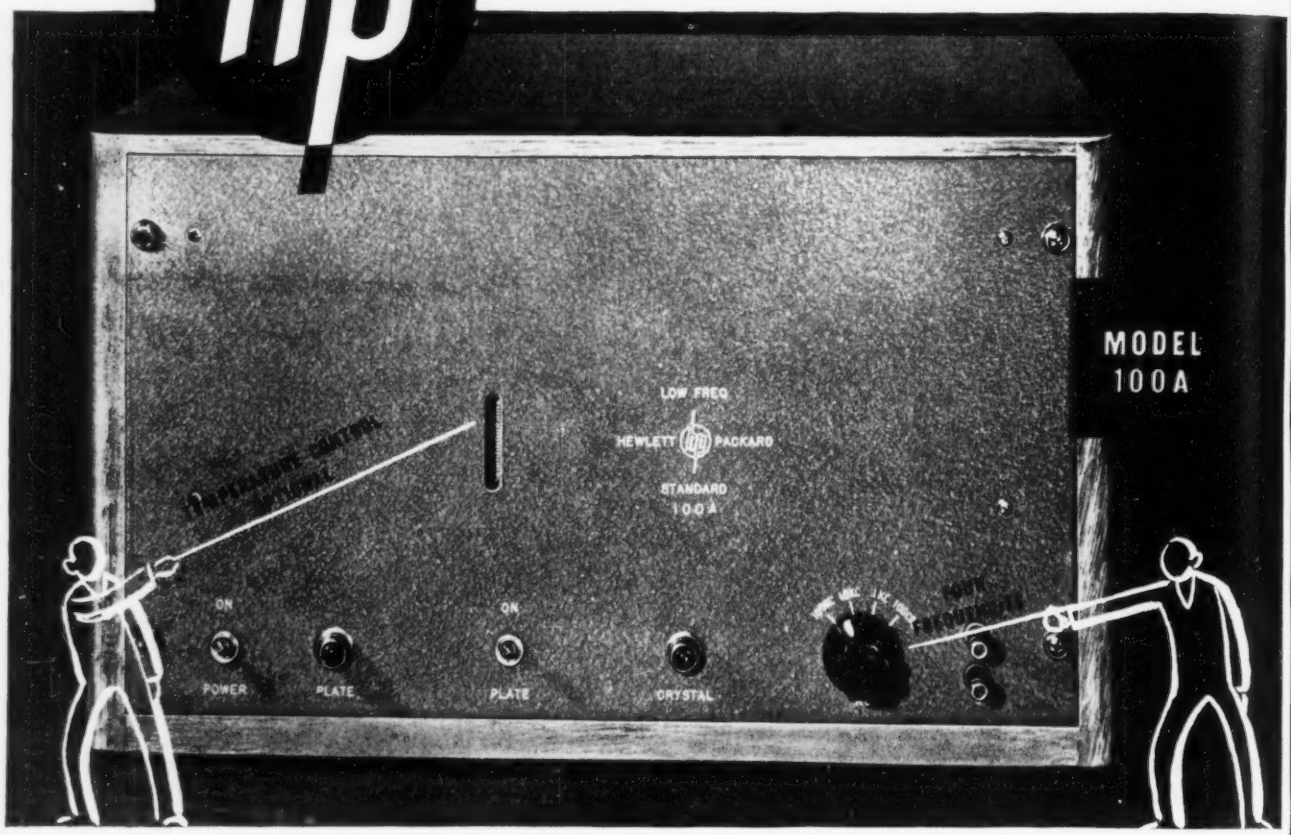
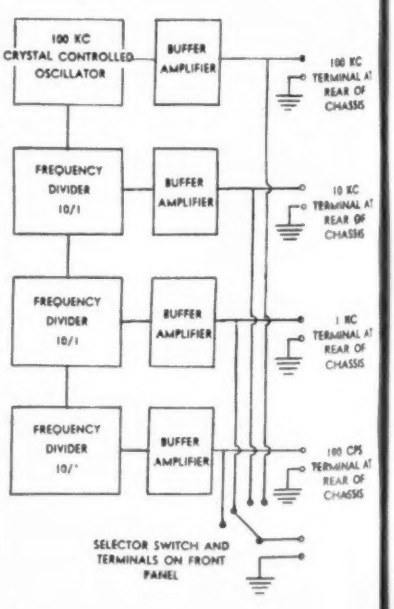
# NEW hp LOW FREQUENCY STANDARD




## Four Standard Frequencies Available Simultaneously

Standard frequencies of 100 cps, 1 KC, 10 KC and 100 KC are supplied through a crystal controlled oscillator and a series of frequency dividers of the regenerative modulator type. The output of each of these frequency dividers is made available separately through a low impedence output system. Thus the *-hp-* Model 100A becomes extremely valuable for production test work because the single instrument will provide standard frequencies at a number of test positions. The output impedence is low enough that long lengths of shielded cable can be used for distribution in the laboratory or test department. Separate terminals are provided as shown in the block diagram.


100 KC CRYSTAL CONTROLLED OSCILLATOR
BUFFER AMPLIFIER
100 KC TERMINAL AT REAR OF CHASSIS
FREQUENCY DIVIDER 10/1
BUFFER AMPLIFIER
10 KC TERMINAL AT REAR OF CHASSIS
FREQUENCY DIVIDER 10/1
BUFFER AMPLIFIER
1 KC TERMINAL AT REAR OF CHASSIS
FREQUENCY DIVIDER 10/1
BUFFER AMPLIFIER
100 CPS TERMINAL AT REAR OF CHASSIS
SELECTOR SWITCH AND TERMINALS ON FRONT PANEL

Make accurate interpolation measurements and standardize such measurements to a high degree, calibrate audio equipment accurately and make many other useful tests and measurements with this Model 100A Frequency Standard. Get the complete details on this new *-hp-* instrument today. Also ask for the fully illustrated *-hp-* Catalog which gives you much valuable information about electronic instruments and how to use them. Write today for yours... there is no obligation whatsoever.

**HEWLETT-PACKARD COMPANY**

662 BOX 1135 H STATION A, PALO ALTO, CALIFORNIA

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## for microscopic precision

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The elaborate care exercised in calibrating the Pioneer* Drift Meter typifies the production techniques which, with superior design, underlie the *precision performance* of Pioneer Instruments.

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provides a scale reading of the angle between heading and track of plane. It is an important member of "The Invisible Crew" of precision equipment which 25 Bendix plants from coast to coast are speeding to our fighting crews on world battle fronts.

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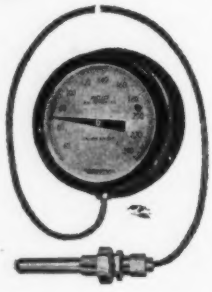

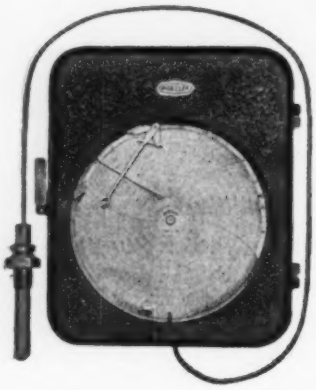

**MOELLER RECORDING THERMOMETERS**

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Also HYGROMETERS
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# Instruments

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*Courtesy Hagan Corporation*

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Published Monthly on the 15th by
THE INSTRUMENTS PUBLISHING COMPANY
1117 Wolfendale Street, Pittsburgh, Pa.

RICHARD RIMBACH, Publisher — Major M. F. BEHAR, Editor

FIELD REPRESENTATIVES

MEMBER Audit Bureau of Circulations

*Boston:* James Condon, 36 Myrtle St. (Lafayette 0829). *New York:* R. K. Farnham, 545 Fifth Ave. (Murray Hill 2-4217). *Cincinnati:* Harold W. Haskett, Keith Bldg. (Main 4260). *Chicago:* Harold W. Haskett, Room 701, 360 N. Michigan Ave. (Franklin 5783). *Pacific Coast:* M. D. Pugh, 2989 Lincoln Ave., Altadena, Calif. (Sycamore 7-2894).

Annual Subscription: U. S. $2.00. Copyright 1943 by The Instruments Publishing Company. Entered as second-class matter January 26, 1932, at the post office at Pittsburgh under the Act of March 3, 1879.


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**The instrument is used to measure cylinder head temperature, engine base temperature, oil temperature, carburetor air temperature, and free air temperature. It also has many other applications, which we cannot emphasize until the war is won.**

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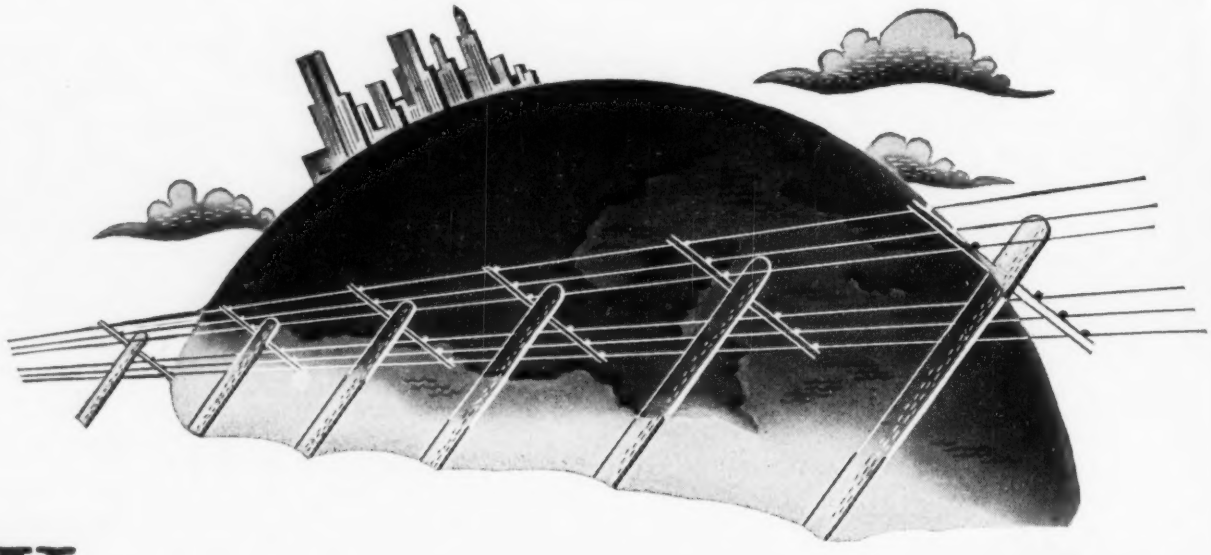
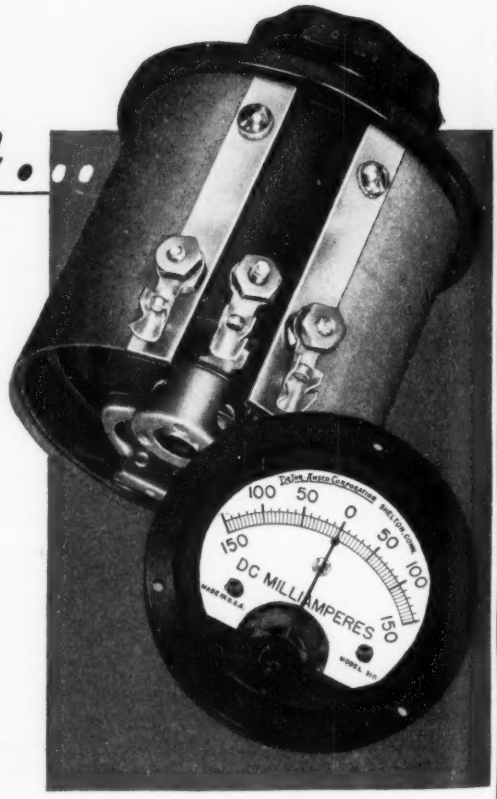


# *Keeping them open . . .*




Imagine what would happen if the electric power lines in your community broke down as you're reading this. Thanks, however, to the Public Utilities and their vigilant band of crack trouble-shooters, the possibilities are indeed slim.

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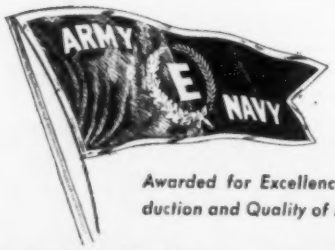


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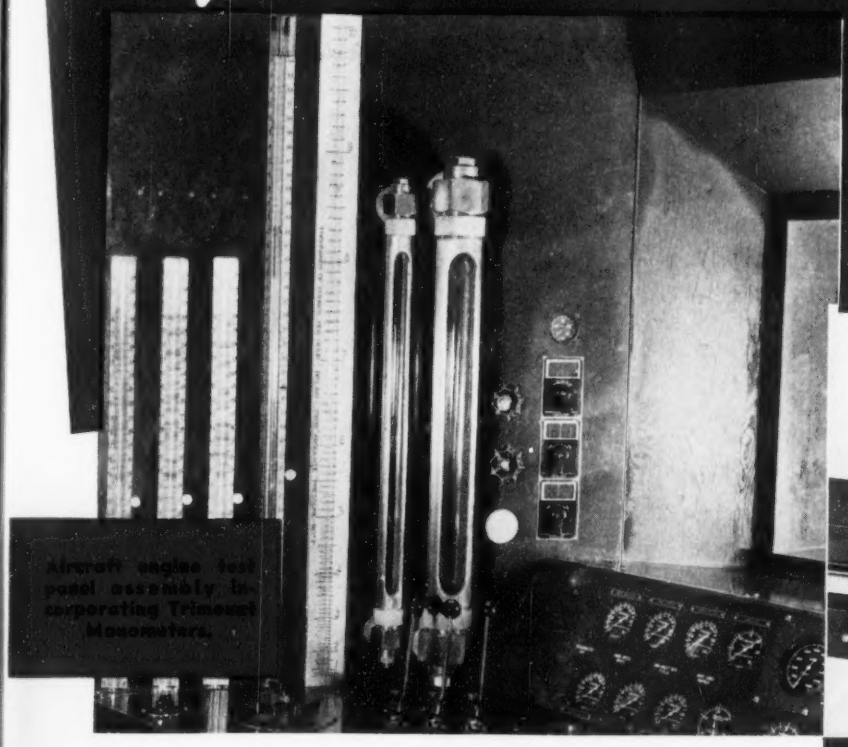

Aircraft engine test panel assembly, incorporating Trimount Manometers.

Closeup of Trimount Thermometer showing compensator for barometric pressure and temperature. Scale Selector on front of panel.

SPECIALIZING in accurate, dependable manometers for all pressure and vacuum measurements, Trimount offers a complete line of instruments from simple U-tube service units to elaborate precision portable panel assemblies.

Trimount is regularly supplying many of the nation's leading manufacturers with specially designed units as well as standard instruments to meet their specific requirements.

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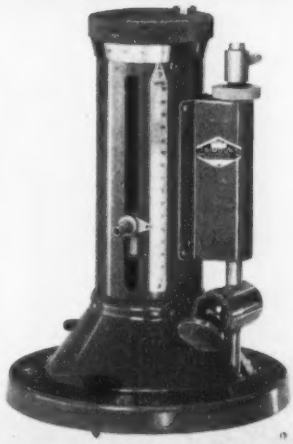
READ BOTH PLUS AND MINUS PRESSURES ON THE SAME INSTRUMENT! Absolute Pressure Gauges, originated by Trimount, permit *direct readings of both plus and minus pressures.*

And now, new foolproof construction permits direct shipment to you, ready for installation! Write for specifications and prices.



Micro-manometer, a precision instrument for calibrating manometers. Range 0 to 150 mm. Reads to 1/100 mm. A jewel of precision! Manufacture licensed under Askania patents.

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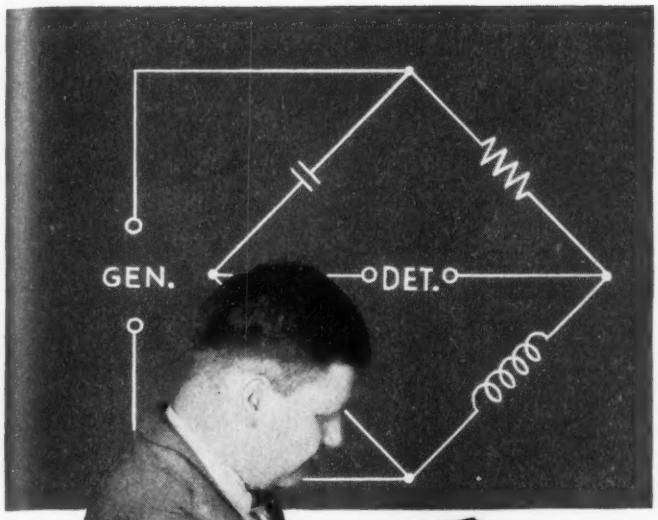
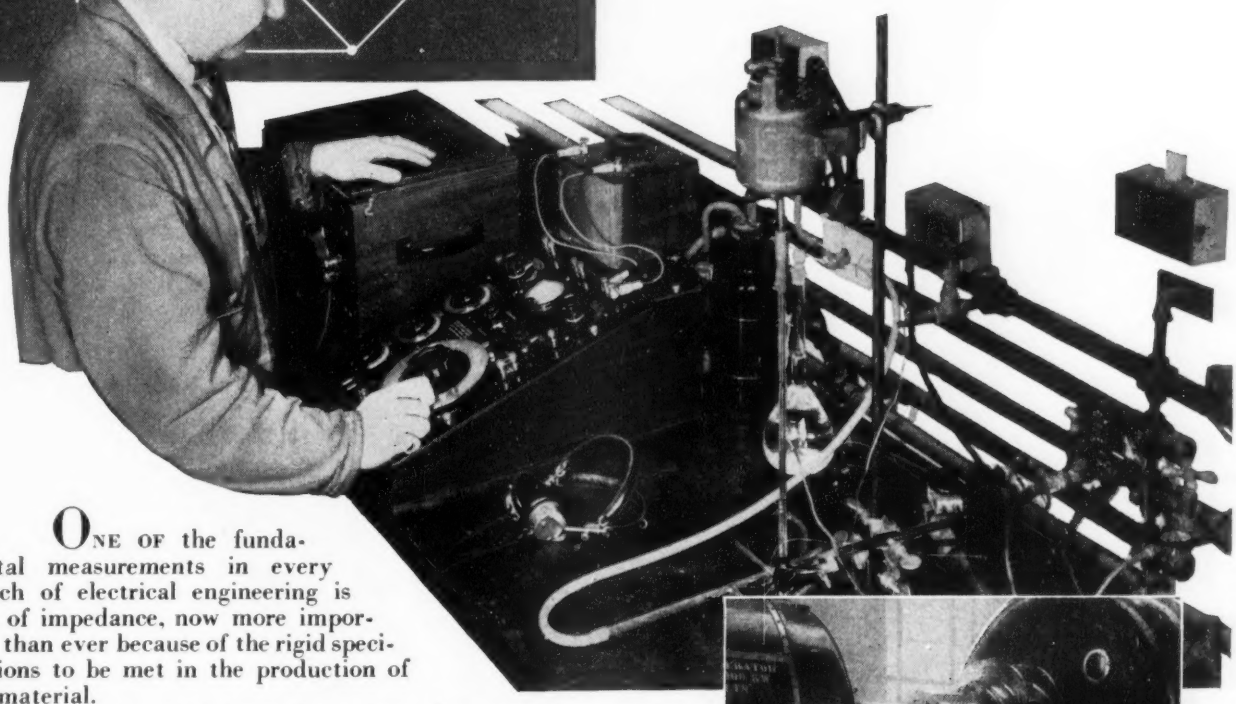
**John Oster Mfg. Co. of Illinois, Dept. N-11, Genoa, Ill.**

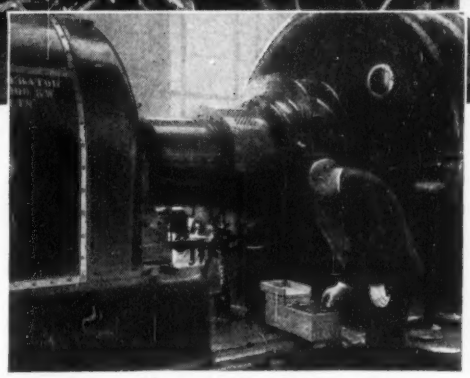



# Impedance bridges



ONE OF the fundamental measurements in every branch of electrical engineering is that of impedance, now more important than ever because of the rigid specifications to be met in the production of war material.

In circuits with lumped constants the accepted means of impedance measurement is comparison by a null method, using an a-c adaptation of the Wheatstone bridge. Impedance bridges have been a General Radio specialty for nearly 25 years. A program of continuous research into methods, circuits, and circuit components has led to increasingly better designs and more useful instruments. For measuring both the reactive and resistive components of impedance at all the important frequencies between 60 cycles and 60 megacycles, there is a General Radio bridge to do the job.



*Measuring insulation resistance on generator.*

*Because all our facilities are devoted to war projects, these impedance bridges are at present available only for war work.*

ARMY (E) NAVY

## GENERAL RADIO COMPANY

GR

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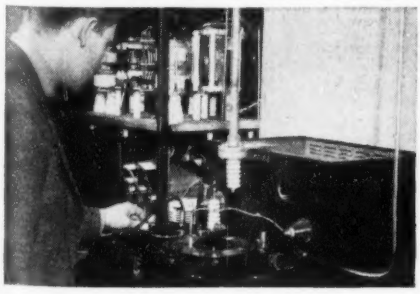
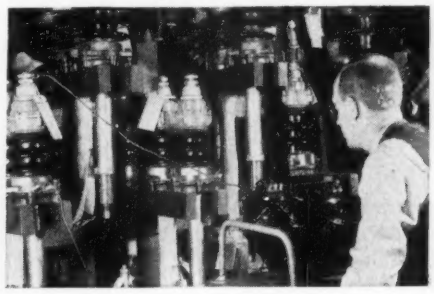
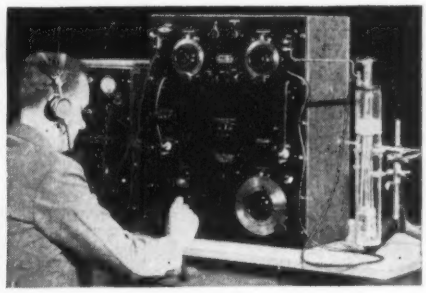
*Radio frequency bridge in broadcasting station.*



*Capacitance test bridge measuring transformer bushings.*



*Capacitance bridge and oil cell.*



Recently a new type cathode-ray tube was called for by our armed forces. Just an idea—something arising out of new conditions—not yet reduced to actual practice—and of course far from production.

Opinion generally was that this new tube might require months to develop, design, produce. Yet DuMont, with its exceptionally close coordination of experimental tube work and actual production, was actually shipping that very tube in quantities within 10 days.

It is performance such as this that has made the name DuMONT the accepted abbreviation for "Cathode-Ray Tube Headquarters."

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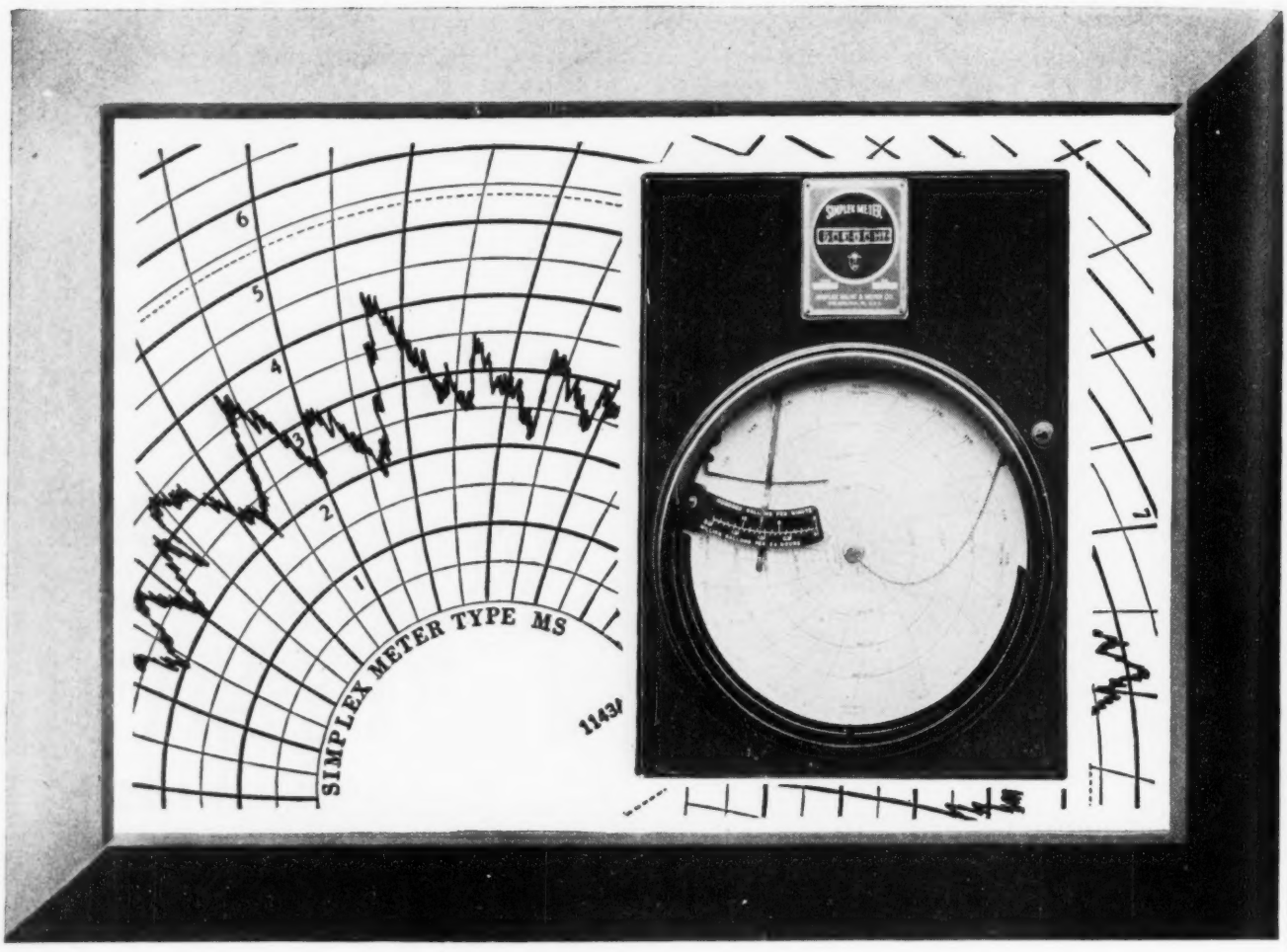


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**What are the facts about steam that can save you dollars — conserve your manpower — increase operating efficiency?**

**The surest FACT FINDER is a Simplex MS Flow Meter on your steam lines, because it puts the finger of suspicion on defective equipment, relative quality of fuel, efficiency of the operating staff — and gives recorded flow rate data — the basis for effective control.**

**What are the reasons for the high accuracy of the MS Meter which makes it ideal for power plant use?**

**(1) The bell shaped float moves in direct proportion to the rate of flow.**

**(2) The direct reading, evenly spaced chart assures the same high accuracy and visibility of readings over the entire flow range.**

**(3) 7 digit totalizer simplifies integrating of flow and adds weeks of continually increasing daily computations before counter returns to zero. The seventh digit is a means of closely checking the flow.**

**(4) Moisture-proof chart paper eliminates errors resulting from stretching and shrinking.**

**(5) The MS meter integrates, records, totalizes — in any desired combination. Remote reading also is available.**

**Put the facts about your steam flow to work for you. Write today for information on the Simplex MS Flow Rate Meter.**

**SIMPLEX VALVE & METER COMPANY**
**6876 UPLAND STREET, PHILADELPHIA, PENNA.**

# Security posted

MANY TIMES every day "surprise attacks" occur along your power line. Some heavy user momentarily stops operation. A sudden over voltage slams like lightning into delicate machines, precision tools or precious vacuum tubes. You can't *see* these blitz attacks but you can't escape seeing the results—higher percentage of rejections, damage to sensitive instruments, premature failure of expensive electronic tubes.

*Every unit, however small, is responsible for its own security.* This cardinal rule of combat applies in production too. That is why, everywhere in industry, you will find SOLA CONSTANT VOLTAGE TRANSFORMERS on duty at important "outguard" posts.

Sola "CVs" are especially designed to protect against surprise overload assaults. They will absorb voltage sags and surges as great as 30%—and still feed constant, rated voltage to your machines. Sturdy Sola sentinels ask no relief. Day and night, without care or supervision, they stick to their posts—instantaneous in action, without moving parts, self-protecting against short circuit.

Many vital points in your production system are vulnerable to attack. Secure them with Sola "CVs". SOLA CONSTANT VOLTAGE TRANSFORMERS are built in standard units from 10VA to 15KVA capacity, or in special units to your specifications.

**Note to Industrial Executives:** *The problems solved by Sola "CV" transformers in other plants and products may have an exact counterpart in your own. Find out. Ask for bulletin GCV-74.*

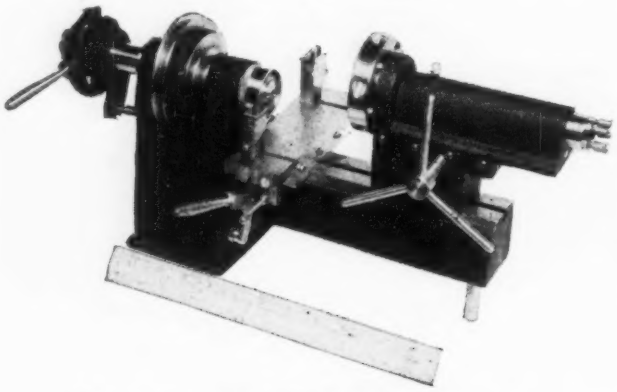
## SOLA Constant Voltage Transformers

**Transformers for:** Constant Voltage • Cold Cathode Lighting • Mercury Lamps • Series Lighting • Fluorescent Lighting • X-Ray Equipment • Luminous Tube Signs Oil Burner Ignition • Radio • Power • Controls • Signal Systems • Door Bells and Chimes • etc. **SOLA ELECTRIC CO., 2525 Clybourn Ave., Chicago, Ill.**

# IMMEDIATE DELIVERY . . .

## INSTRUMENT PRODUCTION LATHES

**With Turret Heads**

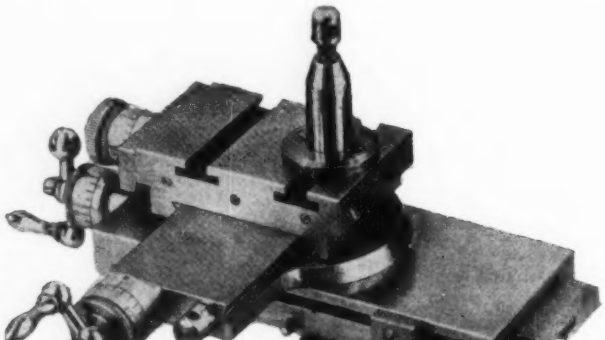


Two Sizes—3/16" and 1/2" Bar Capacity
9" Bed and 4" Swing
Both Sizes Have Lever Collet Closers

**COLLETS**

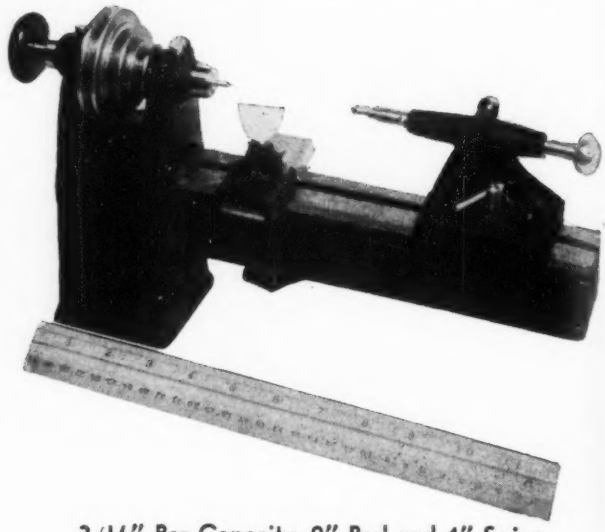
For 1/2" Bar Capacity Lathes Order Style 1A
For 3/16" Bar Capacity Lathes Order Style W W No. 2

## COMPOUND SLIDE REST



**English or Metric Screw Feed**
**Lever Attachment Available**

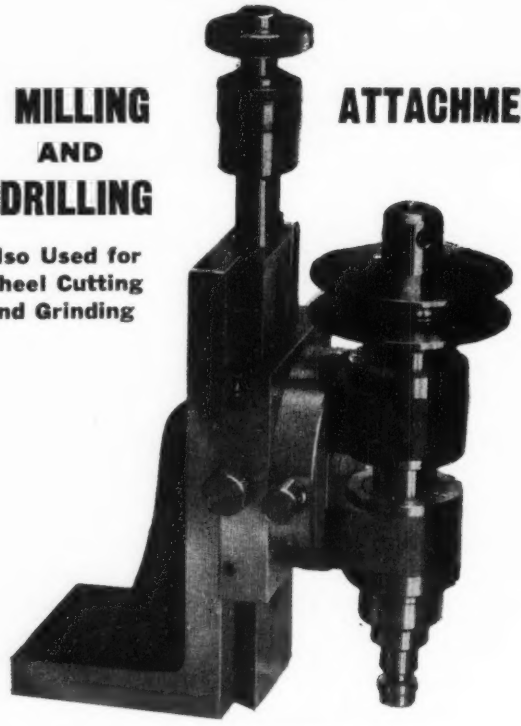
## INSTRUMENT REPAIR LATHES



3/16" Bar Capacity, 9" Bed and 4" Swing

## MILLING AND DRILLING ATTACHMENT

**Also Used for Wheel Cutting and Grinding**



**MOTORS**—1/4 H. P. and Smaller

*For Precision Work on*

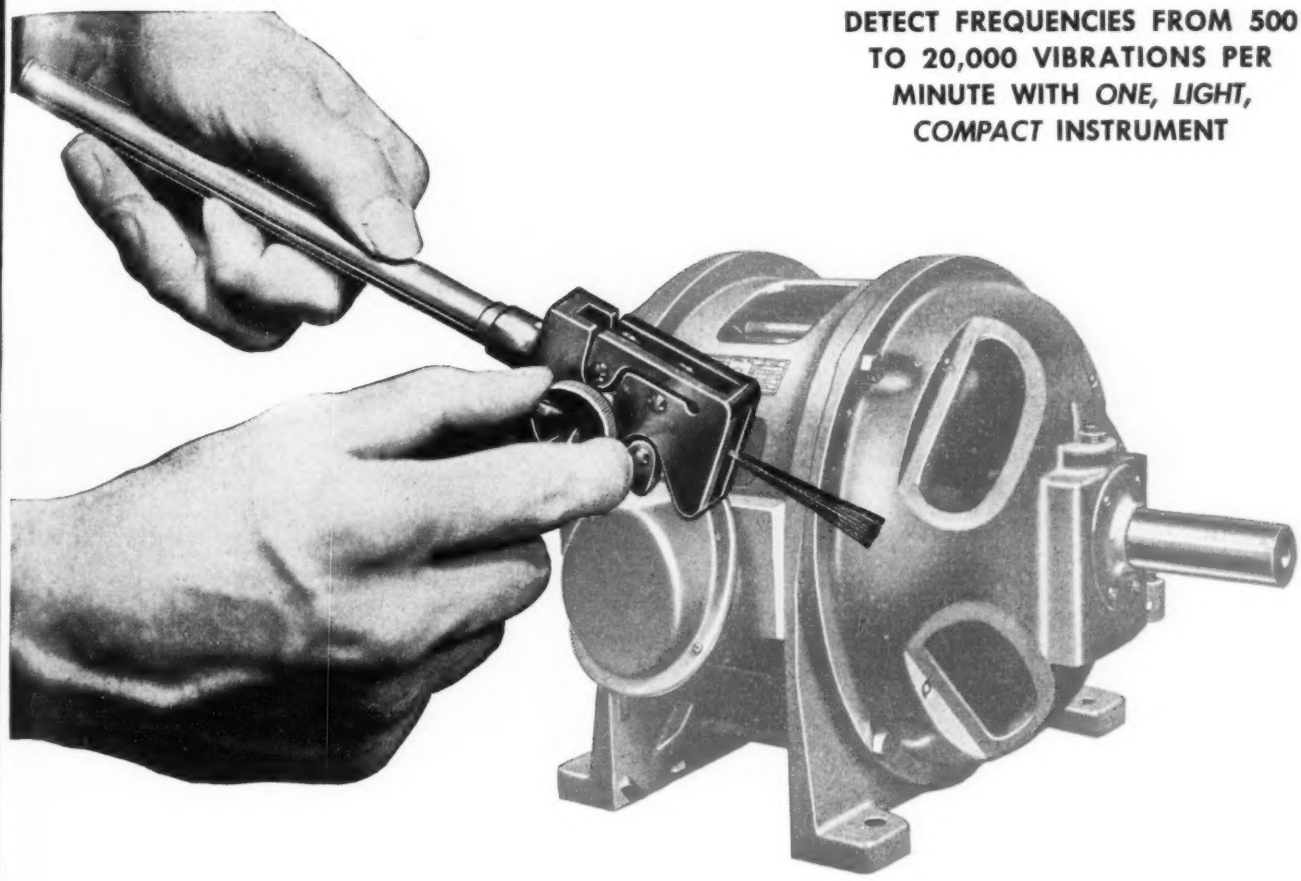
AIRCRAFT INSTRUMENTS
RADIO INSTRUMENTS CAMERA INSTRUMENTS METER INSTRUMENTS
ELECTRICAL INSTRUMENTS AND TIMING DEVICES

# R. P. GALLIEN

AIRCRAFT INSTRUMENT PRECISION EQUIPMENT . . . TOOLS AND SUPPLIES

**220 WEST FIFTH STREET, LOS ANGELES, CALIFORNIA**

**DETECT FREQUENCIES FROM 500 TO 20,000 VIBRATIONS PER MINUTE WITH *ONE, LIGHT, COMPACT* INSTRUMENT**



# ANALYZE VIBRATION BUGS WITH A WESTINGHOUSE *Vibrometer*

Like a doctor's stethoscope, the new Westinghouse Vibrometer helps diagnose machine and motor ills by tracking down the source of troublesome vibrations. It will disclose just what frequencies between 500 and 20,000 cycles per minute are present in a vibrating body.

This unique instrument is built on the old vibrating reed principle, yet is no larger than an engineer's slide rule, and weighs only 8 ounces. By rotating rollers which control its length, the reed is permitted to find its natural frequency.

When this happens, maximum reed vibration occurs and the frequency of the vibration can be read on the calibrated scale.

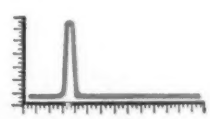
The small size of the Vibrometer permits its use in otherwise inaccessible locations. Light weight makes possible vibration studies of small devices without affecting the vibration being studied.

Call your Westinghouse representative for details. Ask for DD-85-910. Or write direct to: Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pennsylvania, Dept. 7-N.

J-08063

Westinghouse

PLANTS IN 25 CITIES... OFFICES EVERYWHERE

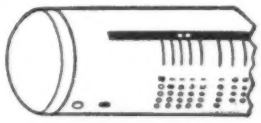


**EXTREME SELECTIVITY**

Reed will register vibrations as small as .0001" double amplitude; will indicate separately all frequencies present and harmonics within its range.

**LARGE REED AMPLITUDE**

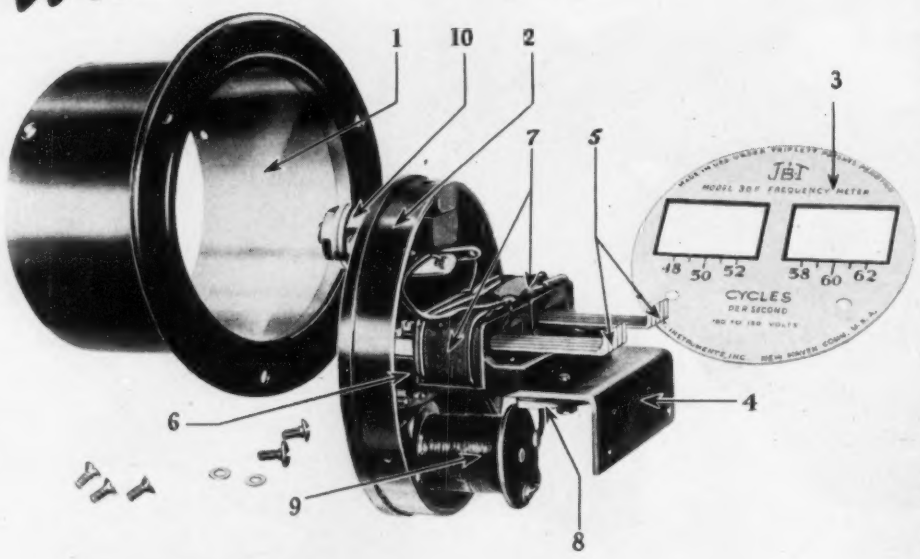
Even though amplitude of the vibration present in a machine is small, it will cause a relatively large reed amplitude.



**DIRECT SCALE READING**

A pointer on the reed's fixed end gives a direct indication of the vibration in cycles per minute on logarithmic scale. In-between frequencies may be interpolated.

# What Makes it RESONATE?




**J-B-T Model 30-F Vibrating Reed Frequency Meter with Case Removed**

1. Case
2. Base
3. Dial
4. Mounting Frame
5. Spring Steel Reeds
6. Reed Mounting Bar
7. Driving Coil
8. Permanent Magnet
9. Series Resistor
10. Terminal Studs

***HOW DOES IT WORK?*** By resonance. As the current flows through the driving coil, the frequency with which the current alternates or is interrupted determines the number of magnetic pulls per second on the reeds. Each reed is preset during manufacture to respond to but one frequency – by combining parts of the proper strength, dimensions and weight. The reed which is "in tune" *RESONATES*, which means that it vibrates to full amplitude – the others little or not at all. Simply READ the REED, and that's your frequency.

***DON'T ALL THE REEDS VIBRATE?*** No, not now. Since the introduction of the original principle, J-B-T basic improvements have virtually eliminated sympathetic mechanical vibration. Reeds on either side of the reed which is vibrating to *full* amplitude also vibrate, but to a much more limited extent, and actually help to indicate the frequency more accurately, particularly if it is fractional.

***CAN THEY TAKE IT?*** Yes, sir. Thousands of J-B-T Vibrating Reed Frequency Meters now in use are standing up where the going is *tough*. Day in, day out they are measuring cycles per second, revolutions per minute, and frequencies for wartime uses.

***HOW DO YOU ADJUST THE METER WHEN IN USE?*** You needn't. Once calibrated at the factory, it is permanently accurate. It requires no adjustment to compensate for wave form, external magnetic fields, voltage variation (±20%), or normal operating temperatures.

***YOU SAY PERMANENTLY ACCCURATE, BUT HOW ACCURATE?*** Within ±0.3% for full cycle increments, ±0.2% for half cycle increments in the 60 cycle range, for instance. A 400 cycle meter is accurate to within ±0.3%.

***WHAT ABOUT POWER CONSUMPTION?*** It is exceptionally low, ranging from less than 2 watts at 400 cycles at 115 volts – to ½ watt at 60 cycles at 115 volts–depending on the model.

***IS THE CONSTRUCTION THE SAME FOR ALL MODELS?*** No. These instruments are available in full range of frequencies, voltages, reed groupings and case sizes. Models are designed to fit the application. J-B-T engineers will be glad to help you get the RIGHT meter for your requirements.

Send for illustrated data bulletin VF-43

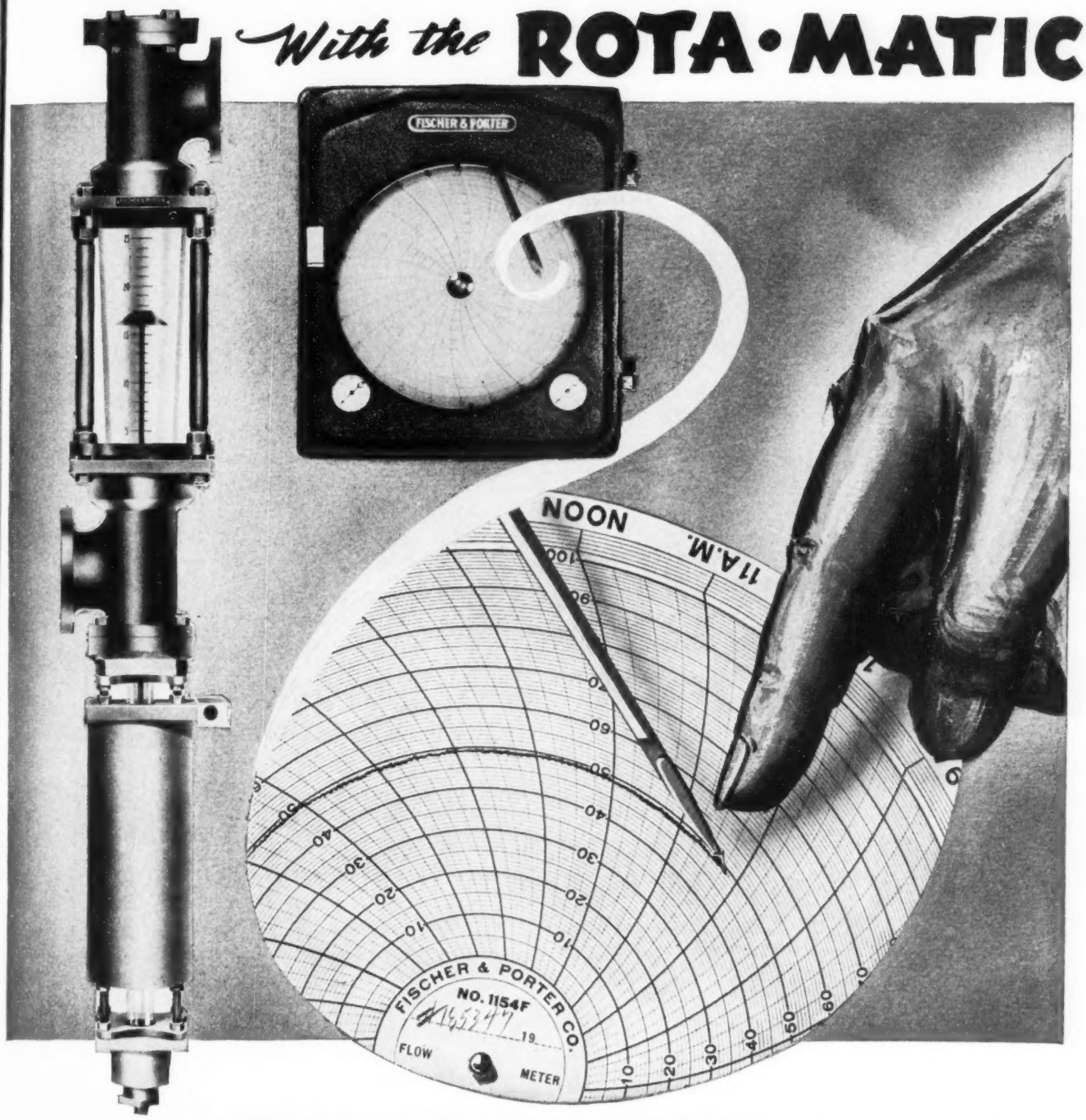
Manufactured under Triplett Patents and/or Patents Pending.

## J-B-T INSTRUMENTS, INC.

**441-J CHAPEL STREET • NEW HAVEN 8, CONNECTICUT**

8-JBT-2

# *With the* ROTA·MATIC




# AUTOMATIC FLOW RATE CONTROL *is at your finger tip*

You just set the control pointer at the flow rate desired. It is as easy as that with the "Rota-matic" to obtain automatic flow rate control.

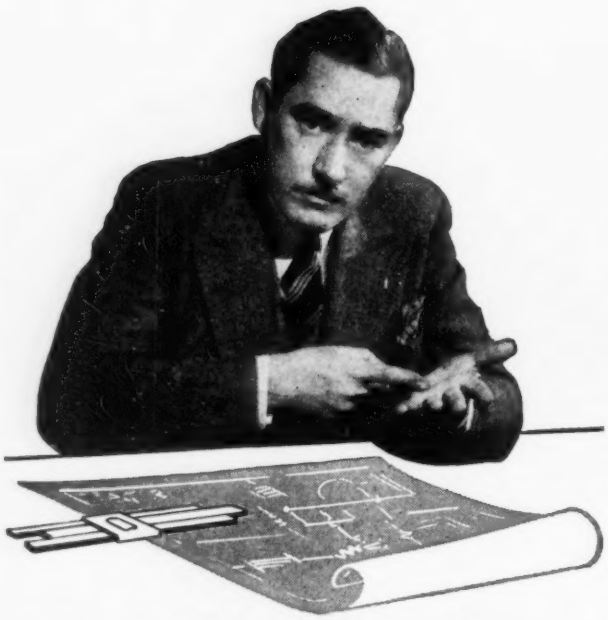
The "Rota-matic" is a rotameter combined with a powerful, new pneumatic controller through an induction bridge circuit. Any tendency of the rotameter float to deviate from the flow control point automatically changes the air pressure upon a diaphragm motor valve placed in the flow line. In this manner, the flow rate is immediately corrected to the desired amount.

This instrument has 100% throttling range and automatic reset for perfect attunement to varying process conditions. The flow control point is adjustable *over the entire range of the rotameter.* It also provides remote recording of flow to supervise and check process results.

In the "Rota-matic" there is available for the first time a flow control instrument combining the automatic response of a modernized pneumatic controller with all the exclusive advantages of the rotameter—high accuracy, instantaneous response, low pressure loss, straight line calibration and wide flow range. It is a new tool for up-to-the-minute instrumentation by those who refuse to be hidebound by the limitations of the fixed-orifice meter. Write for Bulletin 51-B.

**FISCHER & PORTER CO.,** 238 EAST COUNTY LINE ROAD, HATBORO, PA.

F&P ROTAMETERS



# Are You the Man

*Who's Interested In*

# RECTIFIERS?

*—Then We'd Like to Tell You About*

*Copper Sulphide*

**B-L METALLIC RECTIFIERS**

*Selenium*

ENGINEERS who are now busy with Post-War Planning are uncovering many new applications for metallic rectifiers—applications once thought impractical. Are YOU one of these Planners-for-the-Future?

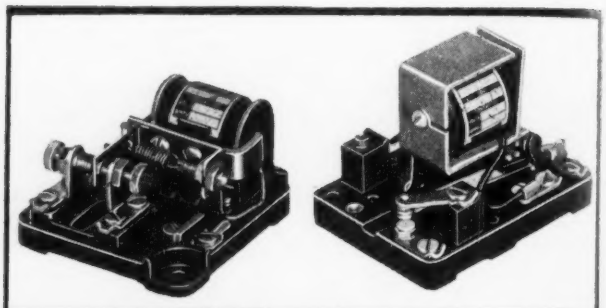
If so, B-L Engineers are eager to help you develop the ideal modern application for simplicity, economy, and efficiency. In wartime use, B-L Metallic Rectifiers have proved their value over and over—and pointed the way to new peacetime developments.

Let B-L engineers help solve your problems of metallic rectifiers, D. C. power supplies and conversion assemblies.

Write Today on your business letterhead for Bulletin R-57 giving full details on B-L Metallic Rectifiers

**THE BENWOOD LINZE CO.** ST. LOUIS, MISSOURI

Designers and manufacturers of Copper Sulphide and Selenium Rectifers, Battery Chargers and D. C. Power Supplies for practically every requirement.



*The* BUY WORD *on* RELAYS

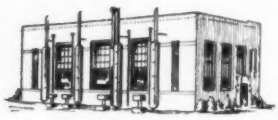
## *"Consult Kurman"*

Some of the smartest users of relays in the country bring us problems on which other manufacturers "give up." Our 23 years of experience in relay manufacture and—"confidence in Kurman"—has a lot to do with it. Very often it's our brilliant Engineering Staff and their constant research, which is always just a step ahead of the field. Whatever your own relay problem may be, it will pay you, also, to—"CONSULT KURMAN." Up to our necks in vital war work, perhaps we can only talk to you. That, too, will pay you.

**KURMAN ELECTRIC CO.**

30-30 NORTHERN BLVD. LONG ISLAND CITY, N.Y.

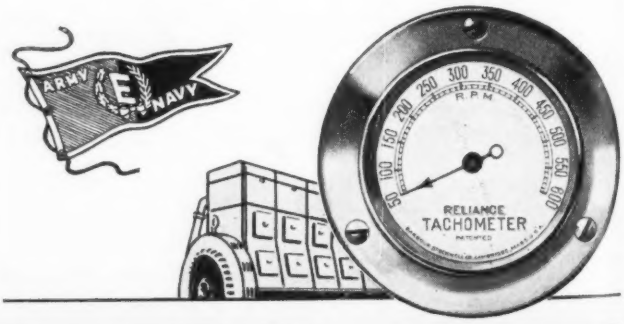
# RELIANCE is a factor in low cost power production



The Robstown, Texas municipal power plant is operated at a profit to tax payers, sells power to home and industrial consumers at low cost.

Each of its Superior engines has a Reliance Tachometer on the gauge board.

Accurate reading of RPM is a factor in low cost production anywhere. Reliance has that accuracy. Each instrument is calibrated individually on the test stand. It's durably built, too, for lasting dependability.

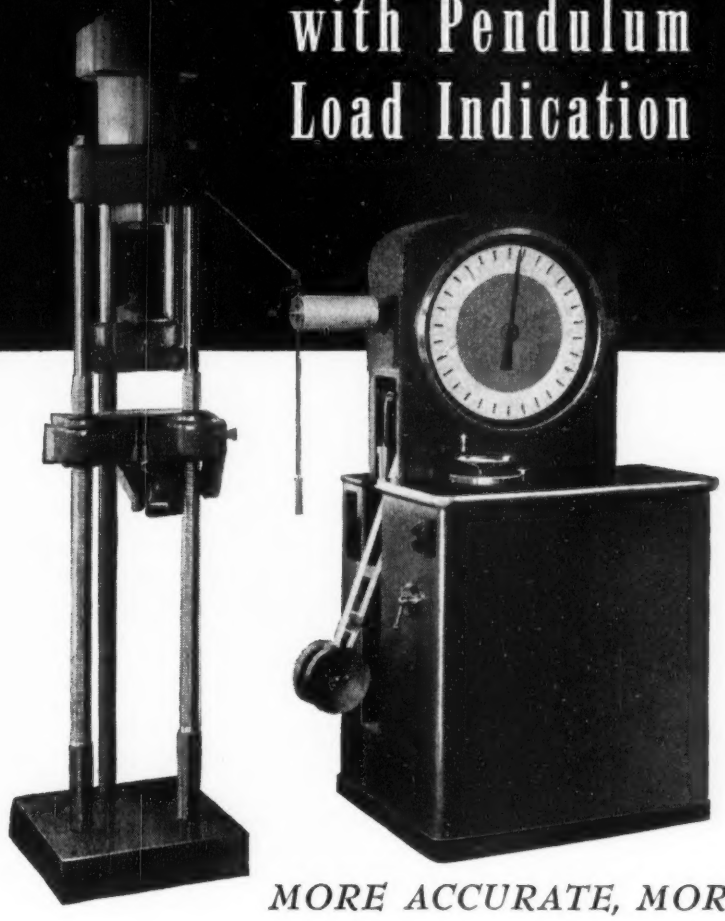



**BARBOUR STOCKWELL COMPANY**

CAMBRIDGE, MASSACHUSETTS

# PRECISION HYDRAULIC TESTING MACHINE

## with Pendulum Load Indication



*MORE ACCURATE, MORE DEPENDABLE FOR PRODUCTION TESTING* ***because:***

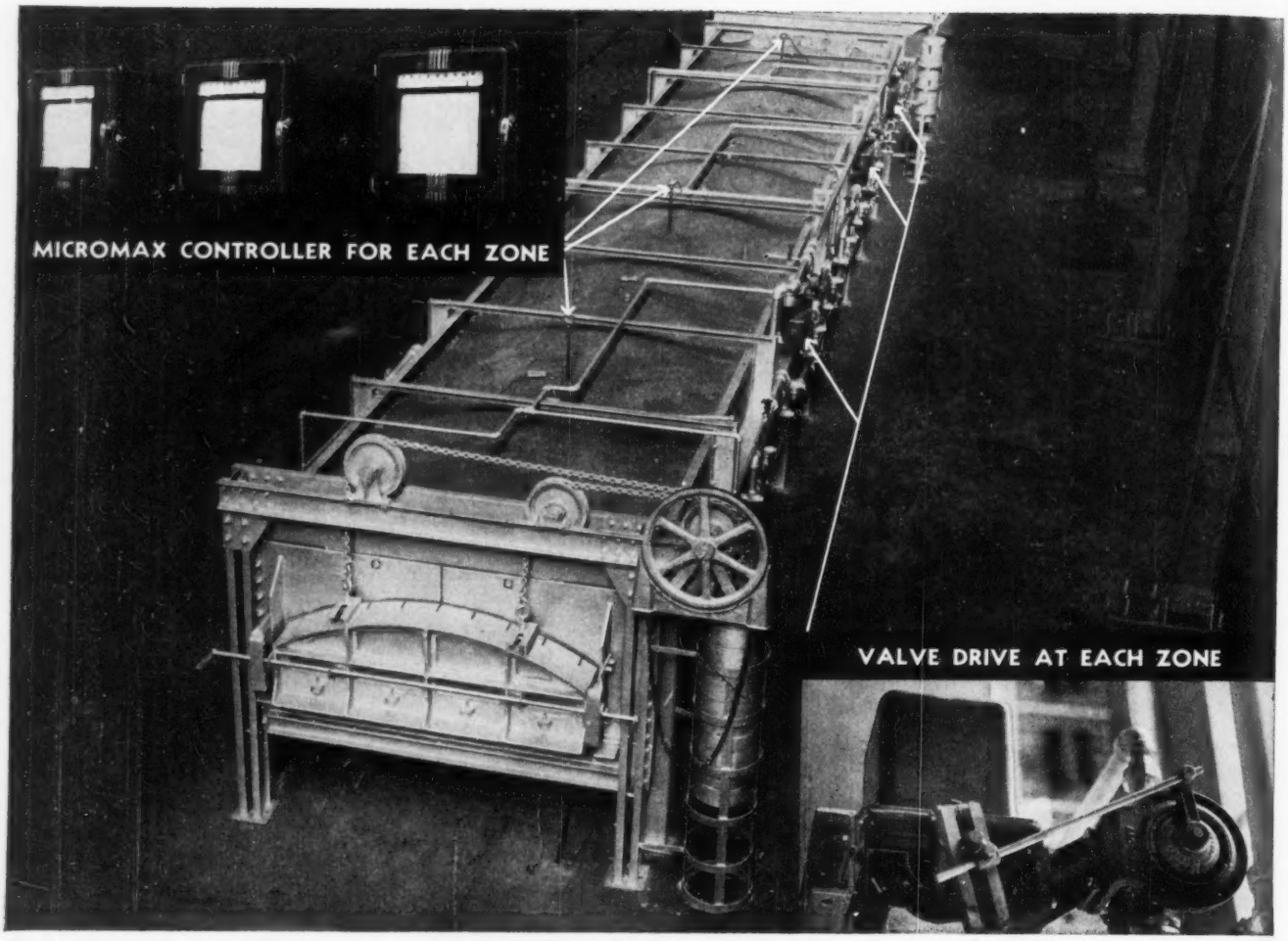
Pendulum load indicator operates on the natural laws of gravitation. ...This principle of operation is not affected by temperature changes or subject to metal fatigue....*Write for descriptive literature and quotations.*

# RIEHLE

## TESTING MACHINES

Division of
American Machine and Metals, Inc., East Moline, Illinois

Other Products: IMPACT TESTERS · VICKERS HARDNESS MACHINES · BRINNELL HARDNESS TESTERS · MEASURING INSTRUMENTS




Gas-fired three-zone wire-patenting furnace, equipped with Micromax Electric Control for holding each zone at exactly the specified temperature.

# OUTPUT OF COLD-DRAWN WIRE

## Is Speeded by Micromax Control Pyrometers

The furnace shown above has a vital war-time job—it is used for patenting, or specially-annealing, the Laclede Steel Company's hot-rolled rod, preparation for the process of cold drawing.

Patenting is an operation in which there's no such thing as too-close temperature control; the closer the control, the smoother and faster the drawing proceeds, and the longer the expensive drawing-dies can last.

Knowing this so well, Laclede's engineers picked Micromax Pyrometers to regulate the patenting temperature—to hold it as steadily on the mark as engineering skill and science will permit. And that's very close—so close that the Micromax chart records are sometimes almost ruler-straight for hours at a stretch.

If you could keep one eye on the Controller and the other on its fuel valve, you'd see how this evenness of regulation is maintained. You'd see the valve's position-pointer shift a bit toward the open or close position; yet the motion of the Controller's detecting mechanism might be so small you couldn't see it at first. There might be another valve-motion, or several more, before you could see that the pyrometer's record had been nudged ever so slightly out of line, and nudged back again as the change in fuel supply brought the temperature back to the control point.

That's what we call micro-responsiveness; the ability to act—correctly—when something tries to upset temperature. If the upsetting factor is small (a change in wind direction, perhaps), the correction is prompt but small. But if the upset is big, as when the furnace load is changed, the correction is both big and fast. Regardless of size, it's always in proportion, to hold temperature in the narrow path needed for high production of war goods.

If you have a furnace—whether for wire, or for cement, castings or anything else—on which you want highly dependable temperature control, tell us and we'll gladly try to help. Or, if you just want a Micromax catalog, ask for N-00A, "Micromax Electric Control".

Jrl Ad N-33A-626(2)

*depends on me!*
A Slogan For All Americans

LEEDS & NORTHRUP COMPANY, 4955 STENTON AVE., PHILA., PA.

LEEDS & NORTHRUP

MEASURING INSTRUMENTS · TELEMETERS · AUTOMATIC CONTROLS · HEAT-TREATING FURNACES

# THE PUBLISHER'S PAGE

## 1. From WPB to Publisher of *Instruments*

Dear Mr. Rimbach: July 27, 1943

Within the past few weeks we have received several communications from would-be subscribers of yours saying that they have been unable to enter subscriptions to your publication "Instruments" as a result of WPB limitation orders. The text of these communications indicate that a false impression has been created by your statements.

The WPB limitation order L-244, as you know, limits the amount of paper a publisher may use but does not stipulate the method by which such curtailment is to be effected. Some publishers have chosen to restrict advertising, some to lowering their weight of paper, some to cutting the size of their magazine, some to restricting their circulation, and some to a combination of these measures. Publishers of small-tonnage magazines get favorable treatment under the order, for they have not yet suffered any cut below 1942 use as have the large publishers.

Apparently your company has elected to greatly increase your advertising and to restrict your circulation to stay within your paper quota. The advertising pages of "Instruments" in the first quarter of 1943 exceeded by 75% the advertising pages carried in the first quarter of 1942. In view of this fact, it is obvious misrepresentation to state to would-be subscribers that you do not have sufficient paper to accept new subscriptions.

In a previous discussion with Mr. W. J. Risley, Jr., Chief of the Magazine Section, Printing and Publishing Division, a representative of your company stated that you could save sufficient paper by reducing margins and paper weights to accept subscriptions by the Armed Services and Members of the Armed Services. Your recent actions are not in accordance with your former statements.

We ask that you immediately cease these misrepresentations of WPB Order L-244 and that you furnish us, at an early date, new figures showing the number of advertising and the number of editorial pages carried by issues, in all issues published to date since the March issue. We ask also for your poundage paper consumption by quarters of 1943. This information should be supplied for each of your two magazines: "Instruments" and "The Instrument Maker."

Looking forward to an early reply, I am

Very truly yours,

STEPHEN G. WRIGHT, Consultant
Printing and Publishing Division

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## 2. Reply from Publisher of *Instruments*

Dear Mr. Wright: August 2, 1943

Your letter of July 27th was received in my office while I was in Washington and I am sorry that I did not have it before as I would have come in to see you. I now plan to be in Washington again on Thursday and Friday of this week and I will get in touch with you.

You state that the text of communications your Division has received indicate that a false impression has been created by my statements. I am sorry to differ with you in this regard as the note we sent out to all prospective subscribers, upon receiving their orders stated:

"In spite of making every economy it is still not possible for us to accept subscriptions as they are received due to War Production Board Limitation Order L-244 which reduces the amount of paper which we could obtain for the publication of our magazine under the previous Limitation Order."

I fully appreciate that Limitation Order L-244 does not stipulate the method by which curtailment is to be effected but it certainly does not give the small-tonnage magazines more favorable treatment, as usually the small publisher has only one publication whereas the large publisher has several of which one or more may serve a consumer field and therefore do not have need for the amount of paper previously used.

In your third paragraph you allege that we have elected to greatly increase our advertising and to restrict our circulation, and you state further that in the first quarter of 1943 *Instruments* exceeded by 75% the advertising pages carried in the first quarter of 1942. Actually there was an increase of 77%, but on checking the advertising in the first quarter of 1943 with that in 1942 of one of the technical monthlies of a large publisher, I find that there was an increase of slightly over 100% in *that* magazine.

I do not quite appreciate your statement "In view of this fact, it is obvious misrepresentation to state to would-be subscribers that you do not have sufficient paper to accept new subscriptions." My answer is that the advertising in a technical journal is just as important to the readers as the articles and we certainly could not do a complete job unless this information was furnished to the readers. Not only are instruments required for the fighting equipment but instruments make possible better guns, tanks, airplanes, ships, shells and armor plate by controlling vital steps in the processes by which these tools of war are produced.

In answer to your fourth paragraph, I am sorry that I must point out that evidently there was some misunderstanding as I did not have the pleasure of meeting Mr. Risley, Jr., when I called at the War Production Board, and no other representative of our publishing company was ever at the War Production Board. Therefore, I cannot agree that my recent actions are not in accordance with my former statements as I never made any statements. In my letter to Mr. Burns dated June 9th, I pointed out that I never made the statements attributed to me mentioned in a letter from Lieutenant Scudder, Chief of the Libraries Branch of the Air Adjutant General's Office.*

As I have never made any misrepresentations of WPB Order L-244 and have no intentions to do so, I am indeed at a loss to understand the last paragraph of your letter. In my letter of June 9th to Mr. Burns I attached charts showing the paper used in 1942 and up to and including May 1943 for both *Instruments* and *The Instrument Maker*. Therefore, if you will refer to the charts which I have furnished to him, only three additional figures need be added: *The Instrument Maker* used 877 pounds of paper in the May-June issue, and *Instruments* used 4687 pounds in the May issue and 4489 pounds in the June issue. In the second quarter of 1942 *Instruments* had 91 pages of advertising and in the second quarter of 1943 163 pages or an increase of 78% as against 77% in the first quarter. The poundage of paper used in the first quarter of 1943 on *Instruments* is 25,897; in the second quarter 14,477. In the case of *The Instrument Maker* it is not possible to report by quarters as the publication is a bi-monthly. Therefore, we must divide the paper of the March-April issue between the first and second quarters which means that for *The Instrument Maker* we used 1,832 pounds of paper in the first quarter and 1,411 pounds in the second quarter.

If I can be of any further assistance to you, please advise me.

Sincerely yours,

RICHARD RIMBACH, President
The Instruments Publishing Co., Inc.

*Lieut. Scudder had written us that "authorities" had informed him that "the Instruments Publishing Co. has stated that it could not now accept subscriptions for the Armed Forces."

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## 3. Last-minute Progress Report, Aug. 7

As promised in my letter to Mr. Wright, I saw him in Washington yesterday, August 6. He requested that I make a revised statement to prospective subscribers and I do so:

"According to the revision of L-244 dated March 26, 1943, The Instruments Publishing Company is entitled to an amount of paper 18% over its 1942 usage. During 1942 the paid subscription list was increased from 5200 to 10500 or an increase of 100%. So far this year the advertising in *Instruments* has increased 77%. As this advertising increase is necessary to take care of the doubled circulation, we do not have sufficient paper to accept new subscribers. All possible economies in the production of the magazine have been made."

RICHARD RIMBACH, Publisher

# Graphical Analysis of Transient Phenomena In Industrial Processes

By KALMAN J. DeJUHASZ

Professor of Engineering Research, The Pennsylvania State College, State College, Pa.

*SUMMARY. The interrelations among liquid level, rate of influx and rate of efflux for a storage vessel are determined by graphical analysis. It is assumed that a constant rate of influx and efflux exists during a small finite time element, whereby the level is changed by a small finite amount which can be graphically determined. The new level determines a new rate of influx and efflux, which again is assumed to be valid for the next time interval, for which the new change of level is determined. Thus, step by step, the entire duration of the phenomenon can be covered in a number of steps. The procedure is applied to nine examples of flow processes, such as suddenly and gradually changing rates of influx and efflux.*

THEORIES of continuous operation of industrial processes deal with the following general problem: Consider a vessel in which liquid is contained at a certain level, into which liquid is supplied at a certain rate of influx, and from which liquid is withdrawn at a certain rate of efflux; the liquid level, rate of influx and rate of efflux being in general variable; determine the interrelations among liquid level, rate of influx and rate of efflux.

The foregoing formulation deals with a system involving liquid flow; there are analogous processes involving flow of energy, thermal and mechanical. For a system involving thermal flow the problem can be formulated as follows: Consider a heat storage device, such as a boiler, containing a medium at a certain temperature, into which heat is supplied at a certain rate of heat units per unit time, and from which heat is withdrawn at a certain rate of heat units per unit time; the temperature in the storage device, the rate of heat supply, and the rate of heat withdrawal being in general variable; determine the interrelations among temperature of stored medium, rate of heat supply and rate of heat withdrawal.

For a system involving mechanical energy flow the problem can be formulated as follows: Consider a storage device for mechanical energy such as a flywheel rotating at a certain speed, to which energy is supplied at a certain rate (power input), and from which energy is withdrawn at a certain rate (power output); the flywheel speed, the power input and power output being in general variable; determine the interrelations among flywheel speed, power input and power output.

It is seen that the liquid level in the vessel is analogous to the temperature in the heat storage device and to the speed of the flywheel; the influx rate (or efflux rate) of the liquid is analogous to the rate of heat supply (rate of heat withdrawal) and to the power input (power output). Similar analogies can be formed for systems involving chemical reactions and electrical magnitudes.

In view of these analogies and for the sake of easy visualization, liquid flow systems only will be considered.

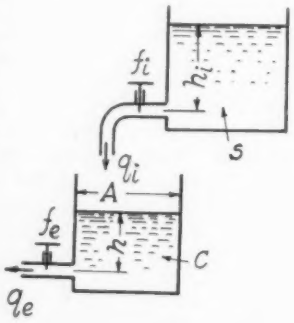


Fig. 1. Elementary Liquid Flow System. *S*—supply tank; *C*—efflux vessel; $f_i$—influx valve; $f_e$—efflux valve; *A*—area of efflux vessel; *b*—head of efflux; $q_i$—rate of influx; $q_e$—rate of efflux.

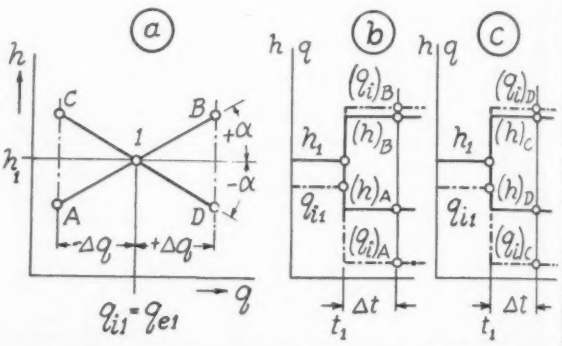


Fig. 2. Basic Procedure of Graphical Analysis in the *q-h* diagram and in the *t-q* and *t-h* diagrams.

*Elementary Liquid Flow System.* An elementary liquid flow system is depicted in Fig. 1, in which *C* represents the liquid container having cross-sectional area *A*, containing liquid at a level *h*. Into container *C* liquid is supplied from supply tank *S* through an adjustable supply valve having effective area $f_i$, at the influx rate $q_i$ volume units per second, this rate being a function of the setting $f_i$ of the supply valve, and of the supply head $h_i$. From container *C* liquid is withdrawn through an adjustable demand valve having an effective area $f_e$, at the efflux rate $q_e$ volume units per second, this rate being a function of the setting $f_e$ of the demand valve, and of the demand head *h*.

For a change *dh* of the level during time *dt*, we can write:

$$A\,dh = (q_i - q_e)\,dt.$$

For some simple cases the nature of this interrelation can be readily visualized. For example, if $q_i$ and $q_e$ change in such a manner that $(q_i - q_e) = \text{constant}$, then

$$\frac{dh}{dt} = \frac{q_i - q_e}{A} = \text{constant},$$

that is, the liquid level sinks or rises at a constant rate. In the particular case in which $q_i = q_e$, $dh/dt = 0$, and the head remains constant. In general, however, both $q_i$ and $q_e$ vary, their values depending on time *t* (for example due to changed settings of the supply valve $f_i$ and/or of the demand valve $f_e$), on the liquid level *h* which is itself variable, and on the actions of the regulatory means incorporated in the system, and responding to changes in the derivatives of *h* so that in general

$$(q_i - q_e) = f\left(t, h, \frac{dh}{dt}, \frac{d^2h}{dt^2}, \ldots\right)$$

as a consequence of which the differential equation

$$\frac{dh}{dt} = f\left(t, h, \frac{dh}{dt}, \frac{d^2h}{dt^2}, \ldots\right)$$

takes a complicated form which in specific cases may involve great, and even prohibitive, mathematical difficulties in its solution.

In recent years much valuable work in this field in this country and abroad (see bibliography) contributed importantly to the clarification of the problem and to its solution for specific cases in industrial practice—with the aid of conventional differential calculus and of the more refined operational methods. These methods, however, have the disadvantage that their applicability is restricted to cases in which the law of variation can be expressed in mathematical functions; and even then such methods require more mathematical

*Acknowledgments.* The author expresses his appreciation to Mr. A. Yorgiadis, Research Associate at The Pennsylvania State College, for valuable aid in checking calculations and making the drawings; and to Messrs. C. E. Mason and P. W. Keppler for their comments and suggestions; and his indebtedness to Major M. F. Behar for his care in checking, editing and arranging the text and for his several suggestions for improving its clarity and completeness.

ability and expertness than is at the command of most engineers concerned with these problems.

In the following analysis there will be employed a graphical method which has been applied in other fields[16] with fruitful results and which has the merits of clarity and of being easily applicable not only to mathematically-expressible conditions but also to cases in which the conditions are defined by graphically-stated data.

*Graphical Analysis.* Process phenomena are closely analogous to transient phenomena in elastic columns, the graphical analysis of which has been treated in detail in previous publications.[16] Therefore only a summary of the method, as applied to process phenomena, will be given here.

Process phenomena involve the following main variables: (1) volume velocities of flow $q_i$ and $q_e$, (2) head of liquid $h$, (3) time $t$. Other variables, such as effective valve areas $f_i$ and $f_e$ also enter, but only implicitly, as they affect the volume velocity of flow. In graphical analysis, interrelations in the process (for example volume velocity of flow as a function of head of liquid), and phenomena (for example head of liquid as a function of time) are presented as diagrams in coördinate systems involving two of the above variables.

Processes involve the concepts of equilibrium, disturbance and transient phenomena. The process is in equilibrium when $q_i = q_e$ and $h = \text{const.}$ A disturbance consists in a change impressed on the existing equilibrium condition, e.g., by changing the effective area of the supply or demand valve. The system will tend to assume a new equilibrium condition. A transient phenomenon, then, is the sequence of conditions which the system assumes in passing from the original to the final equilibrium condition.

The basic and distinctive feature of the graphical analysis is that it deals not with infinitesimal variations but with small finite variations of the variables. Applied to the differential equation of the process it is assumed that values of $q_{i_1}$ and $q_{e_1}$ existing at the instant $t_1$ hold valid for a small time element $\Delta t$, so that we may write:

$$A\,\Delta h_1 = (q_{i_1} - q_{e_1})\Delta t$$

from which $\Delta h_1$ can be calculated, defining the new $h_0 + \Delta h_1$ value existing at time $t_1 + \Delta t$. Assuming that the rate of influx and of efflux are known functions of the head, the new $q_{i_2}$ and $q_{e_2}$ values can be found and for the next $\Delta t$ interval we may write:

$$A\,\Delta h_2 = (q_{i_2} - q_{e_2})\Delta t$$

from which again the $\Delta h_2$ and the $h_0 + \Delta h_1 + \Delta h_2$ can be calculated for the following step. Continuing this procedure the entire duration of the phenomenon can be covered in a finite or infinite number of steps. These steps are performed graphically, in a manner resembling the method of graphic statics. While the assumption of constant conditions during the $\Delta t$ time element involves an error, it will be shown in the later examples that a positive error committed in one step is largely corrected by a negative error committed in the following step.

*Interpretation of the time element $\Delta t$.* In transient phenomena involving elastic columns[16] the time element $\Delta t$ has the physical significance of the time necessary for a disturbance to travel from one end of the column to the other end, i.e., $\Delta t = L/a$ where $L$ is the length of the column and $a$ is the velocity of propagation. In other words, a time element $\Delta t$ elapses before a change impressed at one end of the column makes itself felt at the other end. A transient phenomenon then can be pictured as a series of disturbance waves traveling back and forth in the column until a new equilibrium condition is attained.

It would be possible in process problems, likewise, to choose the $\Delta t$ time element in this manner. But the distance separating the point of supply from the point of demand is usually so short that the time of traversal would be an extremely short time, say a few thousandths of a second, while the usual duration of the entire transient phenomenon in an industrial process is several minutes or even hours. Therefore the number of steps necessary to cover the entire transient phenomenon would be impracticably great. For this reason, as a practical measure, the effect of several or many traversals (possibly hundreds or thousands) is lumped together in one time element $\Delta t$. The general concept is still retained and the transient phenomenon is regarded as a series of disturbances traveling between the point of supply and the point of demand, with a virtual velocity of propagation so slow that it takes the arbitrarily chosen time element $\Delta t$ for a disturbance to travel from the point of supply to the point of demand. Thus the choice of the time element $\Delta t$ has to fit the process under consideration: it should be small enough not to obscure fine details in the phenomenon, and it must be large enough so that the duration of the phenomenon, which is of interest in any particular industrial study, is covered in a reasonable number of steps.

The time element $\Delta t$ having been chosen, the differential equation of the process can be written:

$$A\,\Delta h = (q_i - q_e)\Delta t$$

and writing

$$(q_i - q_e) = \Delta q$$

$$\frac{\Delta h}{\Delta q} = \frac{\Delta t}{A} = \text{const.} = \tan(\pm\alpha)$$

is obtained. This relationship can be represented in the $q$-$h$ diagram by straight lines having the slope $\tan(\pm\alpha)$; such a line will be referred to as a "directrix." The slope can be positive or negative according to whether $\Delta q$ and $\Delta h$ have the same or opposite signs.

Fig. 2a is a $q$-$h$ diagram in which the initial condition of equilibrium, $q_{i_1} = q_{e_1}$ and $h_1 = \text{const.}$ is represented by point 1. It is assumed that this equilibrium condition is disturbed at the instant $t_1$ by changing the volume velocity of flow by the amount $\Delta q$. Then, after the time interval $\Delta t$, i.e., at the instant $t_2 = t_1 + \Delta t$, the liquid head in the container will be $h_2 = h_1 \pm \Delta h = h_1 \pm \Delta q \tan\alpha$. According to whether the change $\Delta q$ was impressed on the influx or efflux and to whether the change is positive (increase) or negative (decrease), four cases can be distinguished, denoted in the diagram by letters $A$, $B$, $C$ and $D$, for each of which:

$$(A)\ q_{i_2} = q_{i_1} - \Delta q;\ q_{e_2} = q_{e_1};\quad h_2 = h_1 - \Delta h$$

$$(B)\ q_{i_2} = q_{i_1} + \Delta q;\ q_{e_2} = q_{e_1};\quad h_2 = h_1 + \Delta h$$

$$(C)\ q_{i_2} = q_{i_1};\ q_{e_2} = q_{e_1} - \Delta q;\quad h_2 = h_1 + \Delta h$$

$$(D)\ q_{i_2} = q_{i_1};\ q_{e_2} = q_{e_1} + \Delta q;\quad h_2 = h_1 - \Delta h$$

It is seen that for cases $(A)$ and $(B)$ in which the change is impressed on the influx velocity, the points defining the condition after the lapse of time $\Delta t$ are situated on a positive directrix $\tan(+\alpha)$ passing through the point 1; for cases $(C)$ and $(D)$ in which the change is impressed on the efflux velocity, the points defining the condition after the lapse of time $\Delta t$ are situated on a negative directrix $\tan(-\alpha)$ passing through the point 1.

This procedure will be applied to nine definite cases, some of which have been treated by previous authors with the aid of mathematical methods:

I. Efflux at Constant Rate; Zero Influx.
II. Efflux and Influx at Constant Rate.
III. Efflux Rate is Function of Liquid Head; Zero Influx.
IV. Efflux Rate is Function of Liquid Head; Influx Rate Constant.
V. Influx Rate is Function of Liquid Head; Efflux Rate Zero.
VI. Both Influx Rate and Efflux Rate are Functions of Liquid Head.
VII. Gradual Opening of Efflux Valve; Zero Influx.
VIII. Harmonically Fluctuating Influx; Variable Efflux.
IX. Plurality of Efflux Vessels in Series.

*Case I. Efflux at Constant Rate; Zero Influx.* This condition is illustrated symbolically in Fig. 3a by a syphon which produces a constant head of efflux $h_e$ as long as the end of the syphon in the vessel is submerged. It is assumed that initially the demand valve is closed, and that the liquid level in the vessel is $h_1$. At $t_1$ instant, the valve is suddenly opened, producing a con-

stant $q_e$ volume rate of flow. Choosing an arbitrary time element $\Delta t$ from the equation

$$\Delta h/\Delta q = \Delta t/A = \tan(\pm\alpha),$$

the slope of the directrix is determined. The phenomenon is represented in the $q$-$h$ diagram, Fig. 3b, in which point 1 defines the initial equilibrium condition, and the $q_e$ = const. line the impressed efflux rate of flow. After the lapse of time $\Delta t$ the liquid head drops to that defined by point 2 situated at the intersection of the negative directrix tan $(-\alpha)$ with the $q_e$ = const. line. This change is regarded as a disturbance traveling towards the influx end where it arrives after the lapse of time $\Delta t$ and finds there the condition of zero influx whereby a new disturbance is created, the new condition being found at point 3 situated at the intersection of the positive directrix tan $(+\alpha)$ drawn from point 2, with the $q_i = 0$ line, i.e., with the $h$-axis. This disturbance travels back towards the efflux end, where it arrives after time $\Delta t$ and finds there the condition of $q_e$ = const. efflux, whereby a new disturbance is created, the new condition being defined by point 4 situated at the intersection of the negative directrix tan $(-\alpha)$ drawn from point 3, with the $q_e$ = const. line. In a similar manner, points 5, 6, . . . are found in the $q$-$h$ diagram.

The history of the change of liquid head can be constructed by erecting the ordinates of the $q$-$h$ diagram on a time-abscissa base, as shown in Fig. 3c. In this figure two diagrams are shown: one containing points 2,4,6, . . . valid for the efflux end, and the other containing points 1,3,5, . . . valid for the influx end. It is seen that each ordinate is regarded as valid for two $\Delta t$ intervals, i.e., for one interval before, and one interval after, the calculated instant. The true liquid head in the first interval is greater than the height of the ordinate and in the second interval it is less than the height of this ordinate. By reason of this fact the two errors compensate each other.

The true history of the change of liquid head is a continuously sloping line, whereas the graphically obtained history is a stepped line. This error can be reduced by choosing a smaller time-element $\Delta t$ whereby the slope of the directrix will be smaller, the heights of the individual steps will be smaller and the number of the steps to cover a given duration of time will be greater. This has been done in Figs. 3d and 3e by choosing one-half of the time-element $\Delta t$ chosen in the previous construction. It is readily seen that in the limiting case, when $\lim \Delta t = 0$, the stepped line will become a line of constant slope, which is the true history of the change of liquid head, as is obtainable mathematically — and also graphically by connecting the mid-

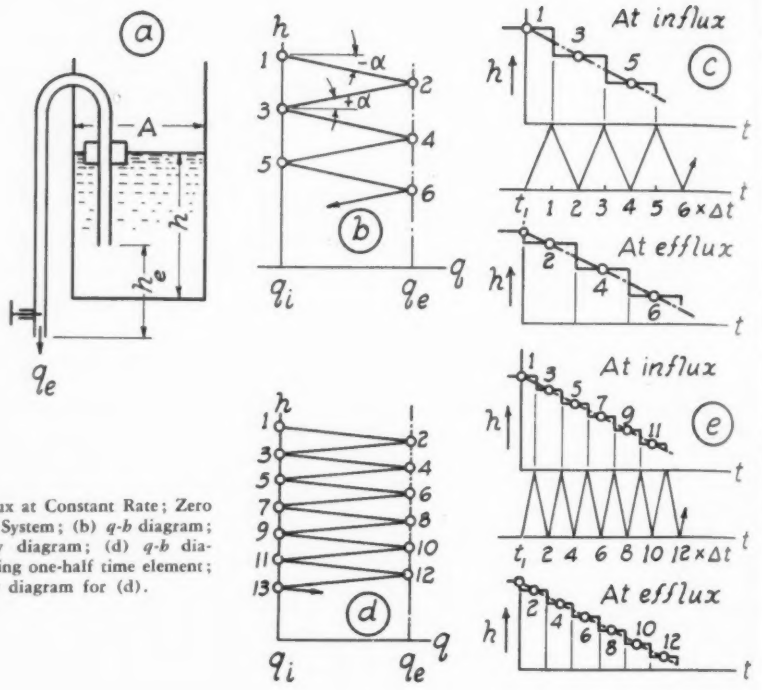


Fig. 3. Efflux at Constant Rate; Zero Influx. (a) System; (b) $q$-$b$ diagram; (c) History diagram; (d) $q$-$b$ diagram assuming one-half time element; (e) History diagram for (d).

points of the steps with a continuous line as shown in Figs. 3c and 3e. It is seen also that in this limiting case the diagram of $h$ will be identical for both the efflux and influx ends.

*Case II. Efflux and Influx at Constant Rate.* This condition can be realized by syphons in both the supply and efflux vessel as shown in Fig. 4. It is assumed that initially $q_{i_1} = q_{e_1}$ and $h = h_1$ = const. At the instant $t_1$ the demand valve is throttled down to such an extent that another constant reduced efflux rate $q_{e_2}$ results. Choosing an arbitrary time element $\Delta t$, the slope of the directrix is determined from the equation

$$\Delta h/\Delta q = \Delta t/A = \tan(\pm\alpha).$$

The phenomenon is represented in the $q$-$h$ diagram, Fig. 4b, in which point 1 defines the initial equilibrium condition, and the $q_{i_1} = q_{i_2} = q_{e_1}$ and the $q_{e_2}$ = const. lines the rates of flow before and after the throttling down of the efflux valve. After time $\Delta t$ the liquid head increases to that defined by point 2 situated at the intersection of the negative directrix tan $(-\alpha)$ drawn from point 1 with the $q_{e_2}$ = const. line. This disturbance is propagated towards the influx end where it arrives after time $\Delta t$ and finds there the condition of $q_{i_2} = q_{i_1}$ influx whereby a new disturbance is created, the new condition being found at point 3 situated at the intersection of the positive directrix tan $(+\alpha)$ drawn from point 2 with the $q_{i_2}$ line. In a similar manner the further points 4,5, . . . are obtained. The history of change of the liquid head $h = f(t)$ can be constructed in a manner similar to that shown in Figs. 3c and 3e but it is omitted in this case.

Reviewing the $q$-$h$ diagrams, Figs. 3b, 3d and 4b, the simplicity of the construction will become evident. Starting from point 1 representing the initial condition, directrices are drawn, forming a continuous broken line between the influx and efflux lines. The procedure is essentially a graphical solution of a differential equation, the directrices representing the indefinite general solution, the starting point representing the initial condition, and the influx and efflux lines representing the boundary conditions for the particular solution.

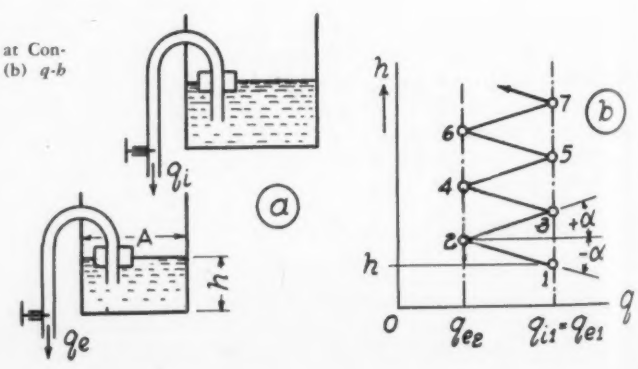


Fig. 4. Efflux and Influx at Constant Rate; (a) System; (b) $q$-$b$ diagram.

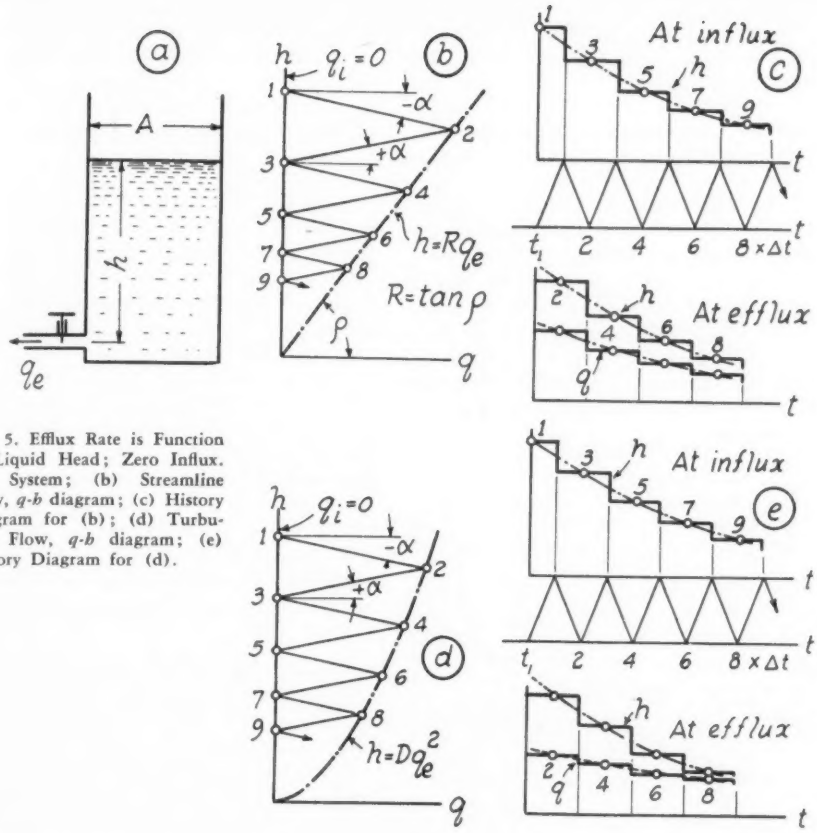


Fig. 5. Efflux Rate is Function of Liquid Head; Zero Influx. (a) System; (b) Streamline Flow, $q$-$h$ diagram; (c) History Diagram for (b); (d) Turbulent Flow, $q$-$h$ diagram; (e) History Diagram for (d).

*Case III. Efflux Rate is Function of Liquid Head; Zero Influx.* This condition is realized by an efflux pipe being connected to the bottom of the efflux vessel, as shown in Fig. 5a. It is assumed that initially the efflux valve is closed: $q_{e1} = 0$, the influx rate is zero: $q_i = 0$, and the liquid head is $h_1$. At the instant $t_1$ the efflux valve is opened. Choosing an arbitrary $\Delta t$ time element, from the equation

$$\Delta h/\Delta q = \Delta t/A = \tan(\pm\alpha),$$

the slope of the directrix is determined. According to whether the efflux is of streamline or turbulent character, two cases can be distinguished:

*(a) Streamline Flow.* The efflux velocity is proportional to the head $h$. This relation is represented in the $q$-$h$ diagram, Fig. 5b, by a straight line passing through the $q = 0$, $h = 0$ point and having the slope $\tan\rho = R$ with the $q$ axis. Starting from point 1 defining the initial condition, a negative directrix $\tan(-\alpha)$ is drawn until it intersects the efflux line at point 2 which represents the state of flow, both as to liquid head and efflux rate at the end of the first $\Delta t$ interval. This disturbance is propagated towards the influx end where it arrives after the lapse of time $\Delta t$ and finds there the condition of zero influx, whereby a new disturbance is created, the new condition being found at point 3 situated at the intersection of the positive directrix $\tan(+\alpha)$ drawn from point 2 with the $q_i = 0$ line, i.e., with the $h$-axis. Continuing this method of construction, the successive points 4, 5, 6, . . . are obtained.

Erecting the $h$ ordinates of points 2,4,6, . . . in the $q$-$h$ diagram as ordinates over a base of time as abscissa the history of liquid head at the efflux end is obtained, Fig. 5c. Erecting the $q_e$ abscissas of points 2,4,6, . . . in the $q$-$h$ diagram as ordinates over a base of time as abscissa, the history of efflux rate $q$ at the efflux end is obtained. Similarly, erecting the $h$ ordinates of points 1,3,5, . . . in the $q$-$h$ diagram as ordinates over a base of time as abscissa, the history of liquid head at the influx end is obtained. The heights of the steps in these stepped broken lines decreases by geometrical progression. It can be shown that in the limiting case, when $\Delta t$ approaches zero, this stepped function will approach an exponential curve, i.e.,

$$h = h_1 e^{-(t/AR)}$$

as has been shown[5] by mathematical analysis. This, too, can be approximated graphically by connecting the midpoints of the steps in the stepped function with sloping straight lines, as shown in Fig. 5d. Theoretically, the vessel will be emptied in infinite time because, according to the exponential equation, $h = 0$ at time $t = \infty$. Of more practical interest, $h = \frac{1}{2}h_1$ at time $t = 0.693\ AR$ (which is simply $\log_e 2$ of $AR$) and, at time $t = AR$, $h = 0.368\ h_1$ (that is to say, $h_1/e$).

*(b) Turbulent Flow.* The efflux head is proportional to the square of the efflux velocity, as represented in the $q$-$h$ diagram by the

$$h = Dq_e^2$$

parabola. The method of graphical construction is similar to that described above, as shown in Fig. 5d, in the $q$-$h$ diagram, and in Fig. 5e, in the $h_1 = f(t)$; $h_e = f(t)$; $q_e = f(t)$ diagrams. In the limiting case when $\lim \Delta t = 0$, the $h = f(t)$ diagram will approach a parabola, and the $q_e = f(t)$ diagram a sloping straight line. Theoretically, the vessel will be emptied in the time

$$T = 2Ah\ (D/h_1)^{\frac{1}{2}} = 2A\ (Dh_1)^{\frac{1}{2}},$$

which is twice as long as it would take if the initial velocity

$$q_{e1} = (h_1/D)^{\frac{1}{2}}$$

were to remain constant.

It is readily seen that efflux according to any other law, even if the law is expressed by an experimentally-obtained curve and not by a mathematical function, can be treated by means of the graphical analysis.

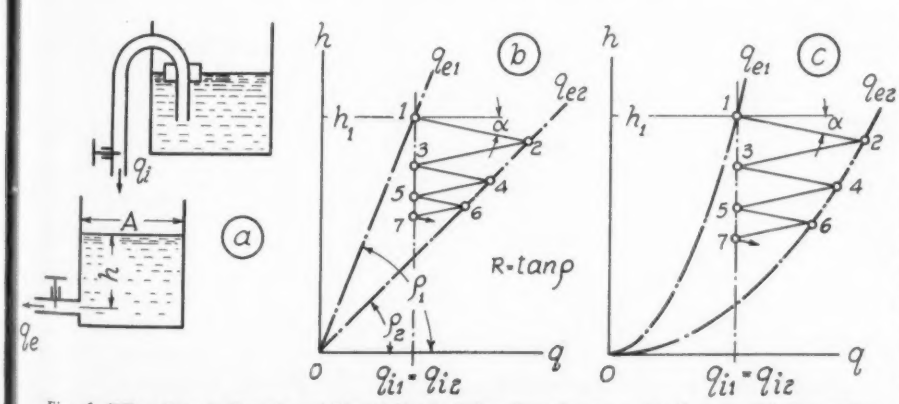


Fig. 6. Efflux Rate is Function of Liquid Head; Influx Rate Constant. (a) System; (b) Streamline Flow, $q$-$h$ diagram; (c) Turbulent Flow, $q$-$h$ diagram.

*Case IV. Efflux Rate is Function of Liquid Head; Influx Rate Constant.* The system is depicted in Fig. 6 showing a constant influx through a syphon from the supply tank, and a variable efflux through a pipe connected to the bottom of the efflux vessel. It is assumed that initially the efflux valve has been open to a certain extent, resulting in the equilibrium condition $q_{i1} = q_{e1} =$ const., and $h_1 =$ const. as defined in the $q$-$h$ diagram by point 1. At the $t_1$ instant, the efflux valve is suddenly

opened more, resulting in an increased rate of efflux, while the influx rate remains at the previous value, $q_{i2} = q_{i1}$.

The graphical procedure is shown for the case of streamline flow, Fig. 6b, and for turbulent flow, Fig. 6c. The treatment is similar to that given in the previous example. It is seen that the process tends to assume a new equilibrium condition, at which again the rate of efflux is equal to the rate of influx, but the liquid level is lowered. Theoretically, the new equilibrium condition will be attained in infinite time. The construction of the history diagrams of the change of efflux is omitted in this case.

*Case V. Influx Rate is Function of Liquid Head; Efflux Rate Zero.* The system is depicted in Fig. 7 in which the supply pipe is shown submerged in vessel $C$. The level in the supply tank is assumed to be constant. The rate of influx into vessel $C$ will be a function of the liquid level in vessel $C$. It is assumed that initially the supply valve was closed, and the level in vessel $C$ was at $h_1$. At $t_1$ instant the supply valve is suddenly opened. The $q$-$h$ diagram of the ensuing transient phenomenon is depicted in Fig. 7b for streamline flow and in Fig. 7c for turbulent flow, for which no further explanation is needed.

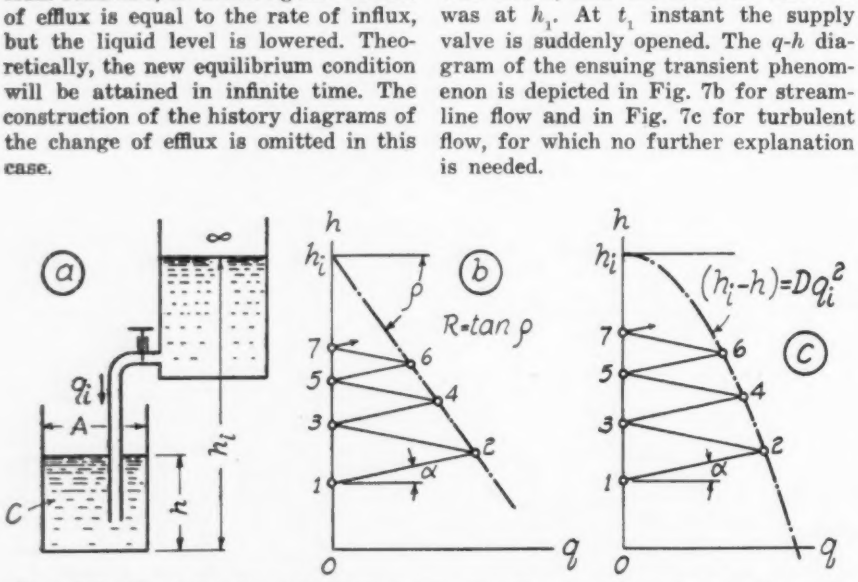


Fig. 7. Influx Rate is Function of Liquid Head; Efflux Rate Zero. (a) System; (b) Streamline Flow, $q$-$h$ diagram; (c) Turbulent Flow, $q$-$h$ diagram.

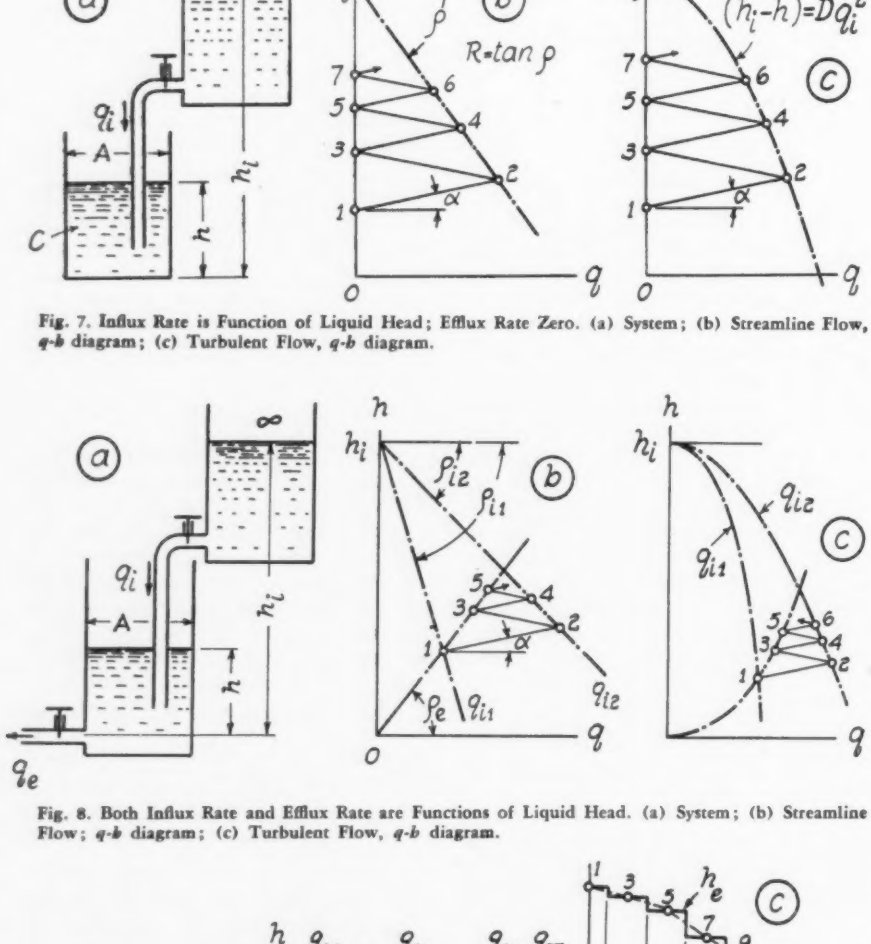


Fig. 8. Both Influx Rate and Efflux Rate are Functions of Liquid Head. (a) System; (b) Streamline Flow; $q$-$h$ diagram; (c) Turbulent Flow, $q$-$h$ diagram.

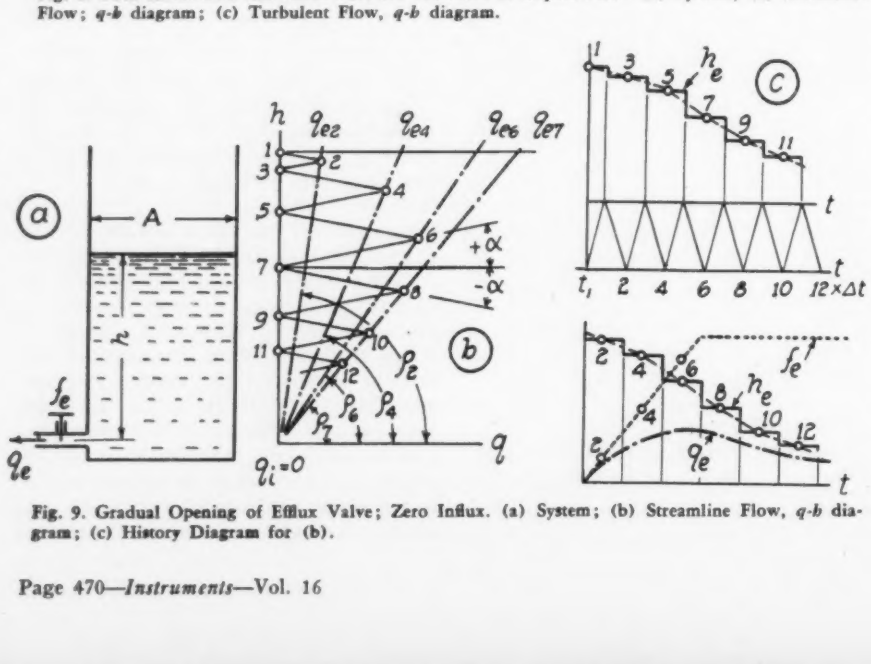


Fig. 9. Gradual Opening of Efflux Valve; Zero Influx. (a) System; (b) Streamline Flow, $q$-$h$ diagram; (c) History Diagram for (b).

In a manner similar to that described above, the case can be treated in which there is efflux at a constant rate and the influx is a function of the liquid head in vessel $C$. The illustration for this case is omitted.

*Case VI. Both Influx Rate and Efflux Rate are Functions of Liquid Head.* The system is depicted in Fig. 8a showing the efflux pipe connected to the bottom of the efflux vessel, and the influx pipe submerged in the efflux vessel. Thus both the efflux rate and the influx rate are functions of the liquid level in the efflux vessel. It is assumed that the level in the supply tank remains constant. In the initial condition of equilibrium both the influx valve and the efflux valve are assumed to be open to a certain extent, and the two flows balanced, $q_{i1} = q_{e1}$ and level $h_1$ constant. At $t_1$ instant the supply valve is assumed to be suddenly opened more, resulting in an increased rate of influx.

The $q$-$h$ diagram is given for the case of streamline flow, Fig. 8b, and for turbulent flow, Fig. 8c. It is seen that the process tends to assume a new condition of equilibrium, at a higher rate of influx and efflux, and at a higher level in the vessel. The history diagram of the transient phenomenon is not given, but it can be readily visualized that the approach to the new equilibrium condition will assume the form of an exponential function in the case of streamline flow, and of an approximately exponential function in the case of turbulent flow. Theoretically, the new equilibrium condition will be attained in infinite time.

In order to give a complete picture of the system, these drawings are small-scale. When actual numerical problems are to be solved, it is of course advantageous to draw to a large scale the portions of the diagrams in which graphical constructions are contained.

*Gradual Change of Conditions.* For simplicity's sake, the "disturbance" considered in the previous examples was a sudden change of conditions. In actual processes, changes are not instantaneous but gradual. Some disturbances of this kind will be analyzed in the following.

*Case VII. Gradual Opening of Efflux Valve: Zero Influx.* The system is depicted in Fig. 9a; the assumptions are similar to those in Case III (Fig. 5.) except that efflux valve is opened not suddenly but gradually: the valve area $f_e$ increasing from the initial value $f_{e1} = 0$ to the final value $f_{e7}$ at a constant rate as shown in Fig. 9c, during $6\ \Delta t$ time intervals. Assuming streamline flow, the flow resistance at each instant is characterized in the $q$-$h$ diagram by a straight line, passing through the $q = 0$, $h = 0$ point and forming slope $\tan \rho = R$ with the $q$-axis. These flow resistances $\rho_2$, $\rho_4$, $\rho_6$, $\rho_7$ are entered in the

$q$-$h$ diagram for the valve areas $f_{e2}$, $f_{e4}$, $f_{e6}$, $f_{e7}$, valid for the $t_1 + \Delta t$, $t_1 + 3\Delta t$, $t_1 + 5\Delta t$ instants, and for the $t > (t_1 + 6\Delta t)$ time respectively. In the graphical procedure, starting from the initial condition, defined by point 1 in the $q$-$h$ diagram, a negative directrix is drawn and brought into intersection at point 2 with the $\rho_2$ line. This disturbance travels towards the influx end where it arrives after the lapse of time $\Delta t$ and finds there the condition of zero influx. This is a new disturbance, the conditions for which are found by drawing a positive directrix from point 2 until it intersects, at point 3, the $q_i = 0$ line, i.e., the $h$-axis. This disturbance travels towards the efflux end where it arrives after a further time interval $\Delta t$ and finds there the valve open to the extent $f_{e4}$, and the new condition will be found by drawing a negative directrix from point 3 to intersect the $\rho_4$ flow resistance line at point 4. In a similar manner the successive points 5, 6, 7, . . . are obtained.

The $q_e$ abscissas of points 2, 4, 6, . . . in the $q$-$h$ diagram are erected as ordinates over a time base, to form the history of the rate of efflux; the ordinates of points 2, 4, 6, . . . are erected as ordinates over a time base, to form the history of liquid level at the efflux end; the ordinates of points 1, 3, 5, 7, . . . in the $q$-$h$ diagram are erected as ordinates over a time base, to form the history of liquid level at the influx end. These diagrams, Fig. 9c, give full information on the progress of the process.

In the case of turbulent flow, instead of the straight-line resistance diagrams, the corresponding parabolas have to be used; otherwise the procedure is similar to that shown for streamline flow and the construction may be omitted in this case.

It is easy to see, furthermore, that the procedure can be applied to any other law of opening the valve, instead of the time-proportional opening shown in the present example.

*Case VIII. Harmonically Fluctuating Influx; Variable Efflux.* The system is depicted in Fig. 10a. It is assumed that efflux takes place through the efflux valve, opened to a constant area, according to streamline flow, as characterized in the $q$-$h$ diagram, Fig. 10c, by a straight line drawn through the $q = 0$, $h = 0$ point at a slope tan $\rho = R$ towards the $q$-axis. Initially the process is in equilibrium, influx taking place at a rate $q_{i_1} = \text{const.}$, as characterized by point 1, being situated at the intersection of the tan $\rho = R$ efflux line and the $q_{i_1} = \text{const.}$ influx line. At $t_1$ instant, the influx rate begins to fluctuate, above and below the $q_{i_1}$ value, as a harmonic function of time, as defined by the $q_i$ line in the $q_i = f(t)$ diagram, Fig. 10b.

The $\Delta t$ time element is chosen 1/24th part of the complete period of influx fluctuation, and the tan $\alpha$ directrix determined. The rates of influx for the instants $t_1 + \Delta t$, $t_1 + 3\Delta t$, $t_1 + 5\Delta t$, . . . are determined from the $q_i = f(t)$ curve, and entered on the $q$-$h$ diagram. Starting from point 1 a positive directrix tan $(+\alpha)$ is drawn, cutting the $q_{i_2}$ line at point 2. This disturbance travels towards the efflux end where it arrives after time $\Delta t$; efflux will take place according to point 3 situated at the intersection of the negative directrix drawn from point 2 and of the efflux line tan $\rho = R$. This disturbance travels towards the influx end where it arrives after time interval $\Delta t$ and finds there influx taking place at the rate $q_{i_4}$, the new condition being defined by point 4 situated at the intersection of the positive directrix tan $(+\alpha)$ drawn from point 3 with the $q_{i_4}$ line. In a similar manner

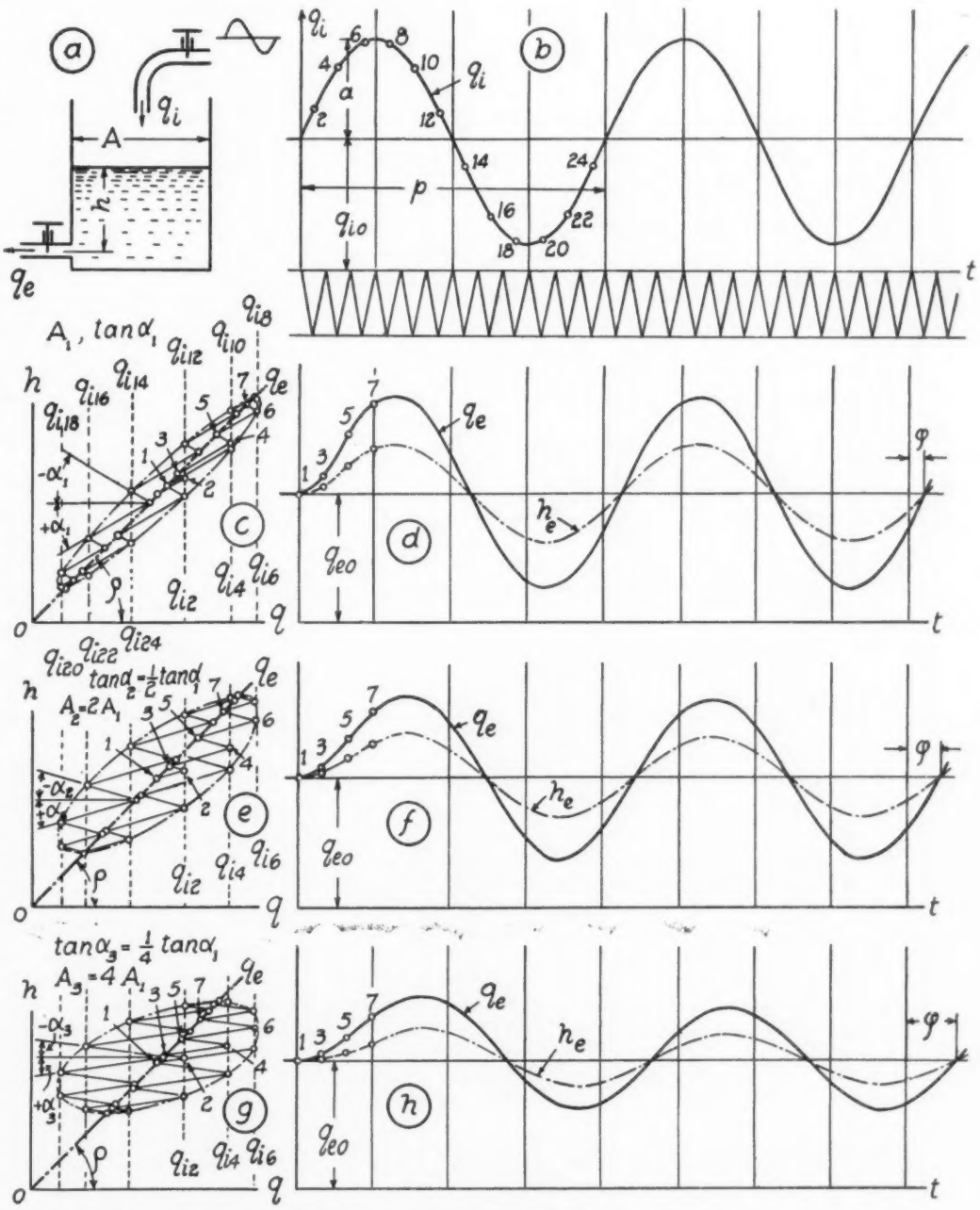


**Fig. 10. Harmonically Fluctuating Influx; Variable Efflux. (a) System; (b) $q$-$h$ diagram; (c) History Diagram for (b); (d) $q$-$h$ diagram for influx fluctuation slower than in (b); (e) History Diagram for (d); (f) $q$-$h$ diagram for influx fluctuation faster than in (b); (g) History Diagram for (f).**

the successive points 5, 6, 7, . . . are found.

For the history diagrams of the rate of efflux $q_e$, and liquid level $h$, the coördinates of the points 2, 4, 6, . . . (for the efflux end) and of the points 1, 3, 5, . . . (for the influx end) are erected on a time base as abscissa, as shown in Fig. 10d. It is seen that both the rate of efflux and the liquid level tend to assume a harmonic fluctuation about their median value, having the same period as that of the influx rate $q_i$, but having a phase displacement in relation to the latter. This result has been found also by mathematical analysis.[7] It can be visualized that as the period of influx fluctuation is increased, or the capacity of the vessel ($A$) decreased, or the resistance to flow ($R = \tan \rho$) decreased, the phase difference $\varphi$ will approach zero; as the period of influx fluctuation is decreased, or the capacity of the vessel increased, or the resistance to flow is increased the phase difference $\varphi$ will approach one-quarter period of the influx fluctuation.

Fig. 10e and 10f show the $q$-$h$ diagram, and the $q_e = f(t)$ and $h = f(t)$ diagrams, respectively, for the case of $A_2 = 2A_1$, the other conditions being the same as for Fig. 10a, b and c. Figs. 10g and 10h show the $q$-$h$ diagram, and the $q_e = f(t)$ and $h = f(t)$ diagrams, respectively, for the case of $A_2 = 4A_1$, the other conditions being the same as for Figs. 10a, b and c. It is seen that the phase displacement $\varphi$ between the influx and efflux diagrams increases as the cross-sectional area of the efflux vessel increases. It can be proven, but the proof is omitted here, that the relationships

$$\tan \varphi = (2\pi/p)AR;$$

$$(q_e)_{max} = q_{e0} + \frac{a}{\{1 + [(2\pi/p)AR]^2\}^{\frac{1}{2}}}$$

(where $p$ is the period and $a$ the amplitude of influx fluctuation) exist, as has been found by previous mathematical analysis.[5]

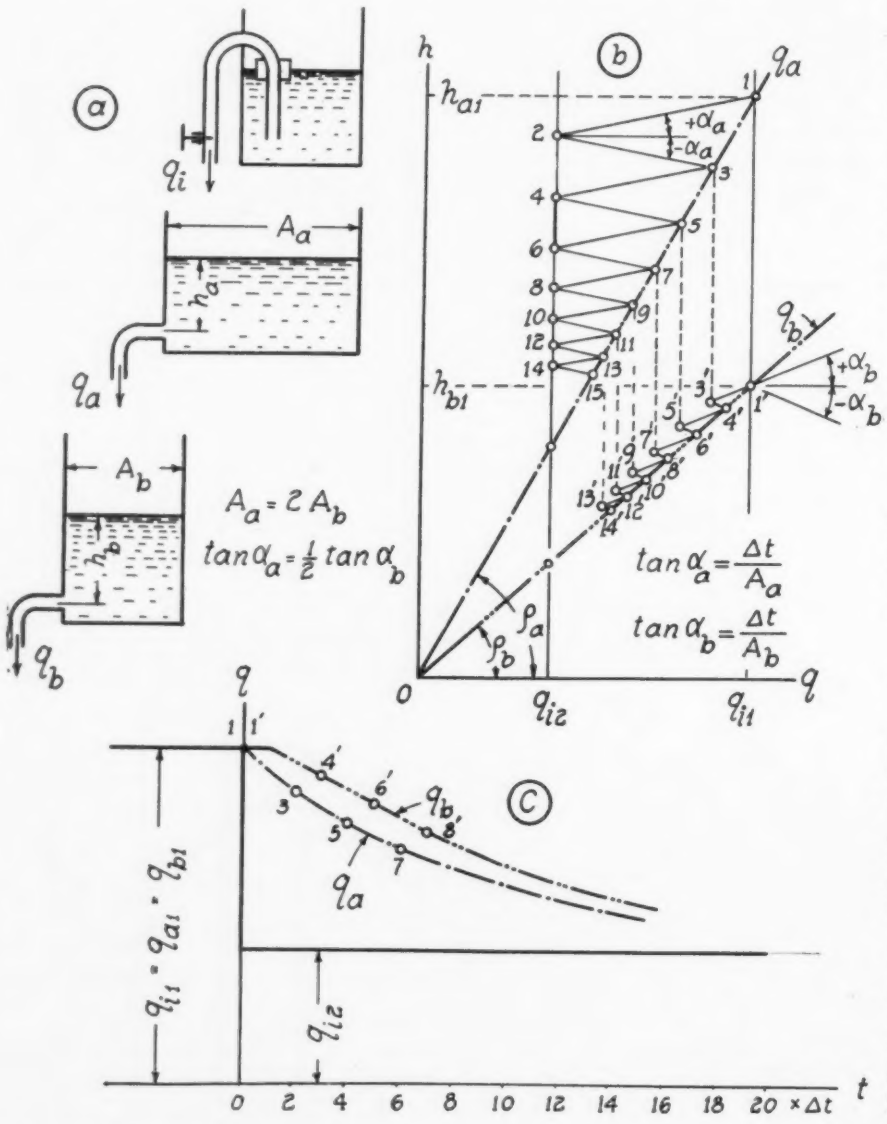


Fig. 11. Plurality of Efflux Vessels in Series. (a) System; (b) $q$-$h$ diagram; (c) History diagram for (b).

*Case IX. Plurality of Efflux Vessels in Series.* The system is depicted in Fig. 11a, showing two efflux vessels in series, into the first of which liquid is supplied from the supply tank at a constant rate. It is assumed that at the instant $t_1$ the rate of supply is changed from the initial value $q_{i_1}$ to a new value $q_{i_2}$ and is kept constant. As a consequence of this change the liquid levels in the two efflux vessels will tend to assume new equilibrium values. The construction of the $q$-$h$ diagram is shown in Fig. 11b and the history of the rates of efflux in the two efflux vessels approach the new rate of influx asymptotically, the one from the first efflux tank more rapidly, the one from the second efflux tank more slowly. This result is in agreement with expectation and with mathematically-obtained previous results.

The graphical method described could be applied to many more problems of interest in industry but the treatment of all possible cases is beyond the scope of this article. Nevertheless it is believed that even the few simple examples treated in this article will serve the purpose of arousing interest in, and forming an introduction to, this simple, clear and fruitful graphical method for analyzing industrial process problems.

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BIBLIOGRAPHY—IN CHRONOLOGICAL ORDER (EXCEPT FOR No. 16)

(1) Th. Stein. "Selbstreglung." *Zeitschrift Verein deutscher Ingenieure*, vol. 72, 1928, pages 16, 209, with 20 figs. and 3 tables of characteristics. Quantitative treatment of time effects in automatically-controlled processes.

(2) M. F. Behar. "Fundamentals of Instrumentation." Instruments Publishing Co. Pittsburgh, 1932. Chapter III, pages 53-80, deals with the performance of automatic controllers. Graphical solution of dead-time dead-zone relation; qualitative discussions of other lags.

(3) J. J. Grebe, R. H. Boundy & R. W. Cermak. "The Control of Chemical Processes." *Trans. A.I.Ch.E.*, Vol. 29, 1933, pages 211-256; with 19 figs. Largely devoted to process lags and reports experimental results obtained with improved automatic-control system.

(4) E. S. Smith, Jr. "Automatic Regulators, Their Theory and Application." *Transactions A.S.M.E.*, Vol. 58, May 1936, 291-303; with 18 figs. Essential elements and characteristics of automatic regulators; sensitivity, speed, power and stability.

(5) C. E. Mason. "Quantitative Analysis of Process Lags." *Transactions A.S.M.E.* Vol. 60, 1938, pages 327-334; with 12 figs. Equations describing the behavior of elementary thermal systems; a method is suggested for the concrete representation of industrial processes by easily visualized comparable form of liquid-level systems.

(6) C. E. Mason & G. A. Philbrick. "Automatic Control in the Presence of Process Lags." *Transactions A.S.M.E.*, Vol. 62, May 1940, pages 295-304; with 10 figs. A specific liquid-level system is assumed, as a model for a typical industrial process; several types of controllers are considered as regards their performance on the assumed system; suggestions for obtaining practical theorems for the technology of automatic control; bibliography; discussions.

(7) C. E. Mason & G. A. Philbrick. "Mathematics of Surge Vessels and Automatic Averaging Control." *Transactions A.S.M.E.*, Vol. 63, 1941, pages 589-561; with 8 figs. Properties of surge vessels, as influenced by externally applied controls; control systems of various types are examined under significant assumed conditions; bibliography; discussions.


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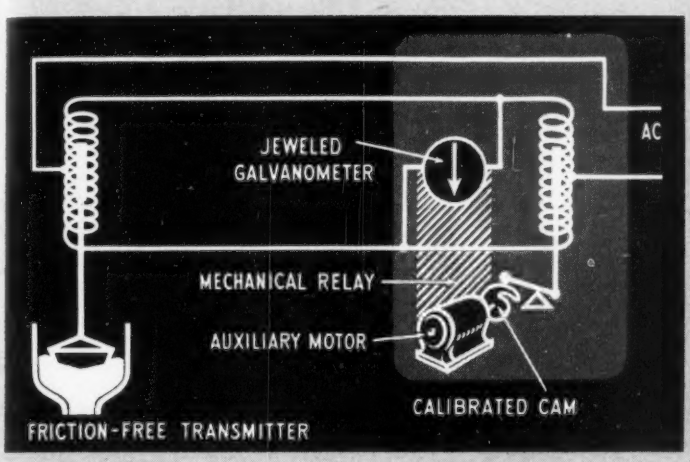


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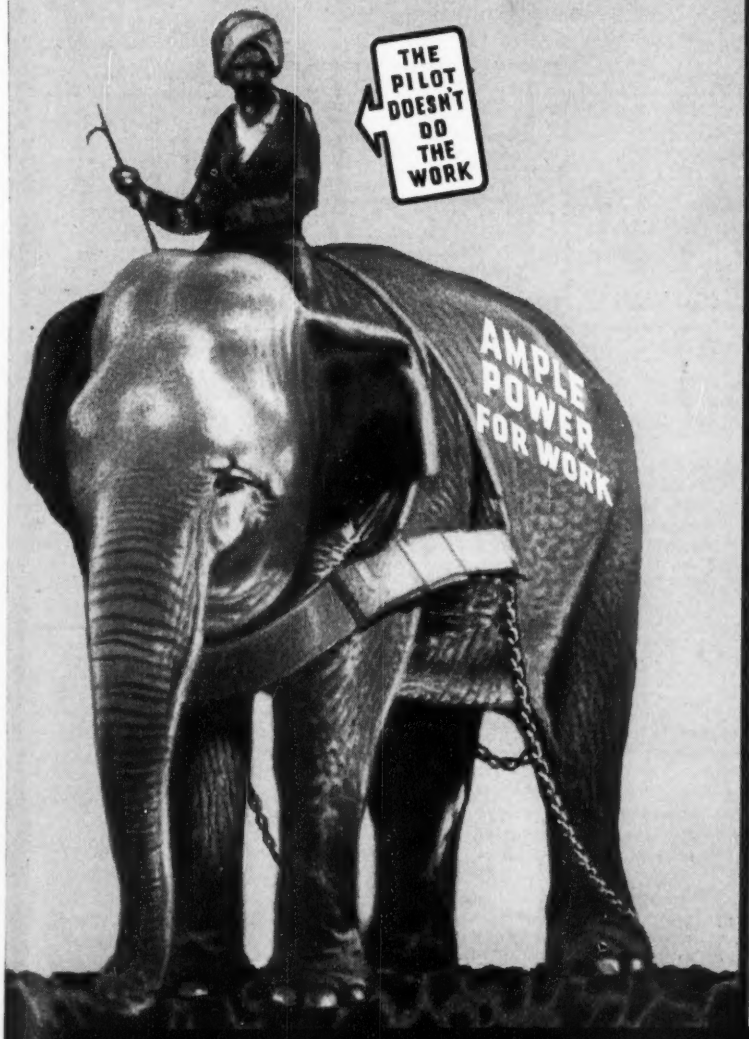


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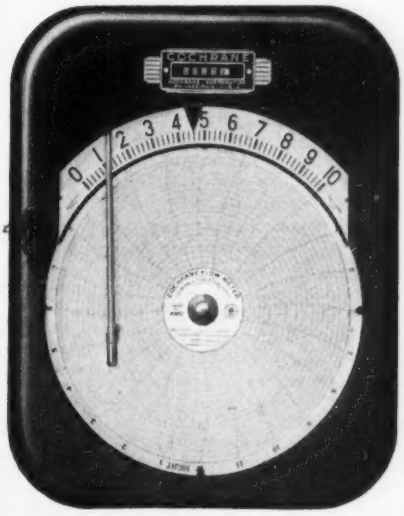


# COCHRANE FLOW METERS

# Forced-oscillation Approach to the Problem of the Automatically-Controlled Continuous Process

By PHILIP R. EWALD
Sheffield, Alabama

[Mr. Ewald's article began as a blackboard talk (without prepared manuscript) before the Southeastern Section of the American Physical Society. At *Instruments'* request he wrote it and sent us sketches. Even from this first draft it was obvious that Mr. Ewald had made a valuable addition to those mathematical treatments which can be grasped by most of our subscribers in industry. The article in that form, with over-simplified circuit diagram, broad generalizations, etc., was no doubt suitable for a scientific journal. In order to make it suitable for *Instruments* subscribers, implicit assumptions scattered through it had to be stated explicitly. Omissions of no consequence to physicists or chemists turned out to be serious from the viewpoint of Instrumentation. In sort, the Instrumentation problem was not even stated. With Mr. Ewald's permission we have taken his assumptions; added other essential ones; put them all down in words and in diagrams; and formulated the problem, as follows:]

## Introduction—Statement of the Problem

By M. F. Behar

An ideal two-capacity-process automatic-control circuit is shown in Fig. 1. The condition to be controlled is temperature: the purpose of the installation is to raise to a constant temperature $T_C$ a flow of water passing through a heat exchanger. The water flow $Q_W$ is constant, but the inlet temperature varies (whence the need of control). Before a condition can be controlled, it must be measured, so the outlet temperature $T_W$ is measured by the controller's primary element, which is in direct contact with the water and is assumed to be ideal. This temperature is indicated ($T_I$) and recorded. The indicating (and recording) element is assumed to be inertialess, lagless and accurate. Thus $T_I = T_W$ at all times—which assumption, though contrary to experience, may be justified by assuming that application lags are enormously greater than measuring-system lags.

The controller's measuring system is not only ideal in its sensitivity and freedom from thermometric lag and inertial lag, but the displacement of its indicating pointer obeys a perfectly linear scale law, so that the instrument scale, which is uniformly graduated, represents a portion of the thermodynamic scale of temperature. For convenience, this instrument scale-range is marked "0" to "100" and the setting-point is exactly half-way up the scale.

Perfect automatic control may be said to be an unattainable ideal for the reason that a controller only starts correcting when a correction has to be made. So long as the outlet temperature is "exactly" 50° (so long as $T_I = T_C$) the controller remains inoperative: no command is transmitted from the instrument to the valve. Not until a departure ($T_I \neq T_C$) occurs *need* the controller act. The controller is so designed that it *will not* act until a departure occurs. Finally, the controller will not act until its measuring system responds to a measurable departure

$$\Delta = T_I - T_C > Z_D$$

where $Z_D$ is the dead zone.

In any mathematical treatment it may be assumed that $Z_D$ is an infinitesimal, so that

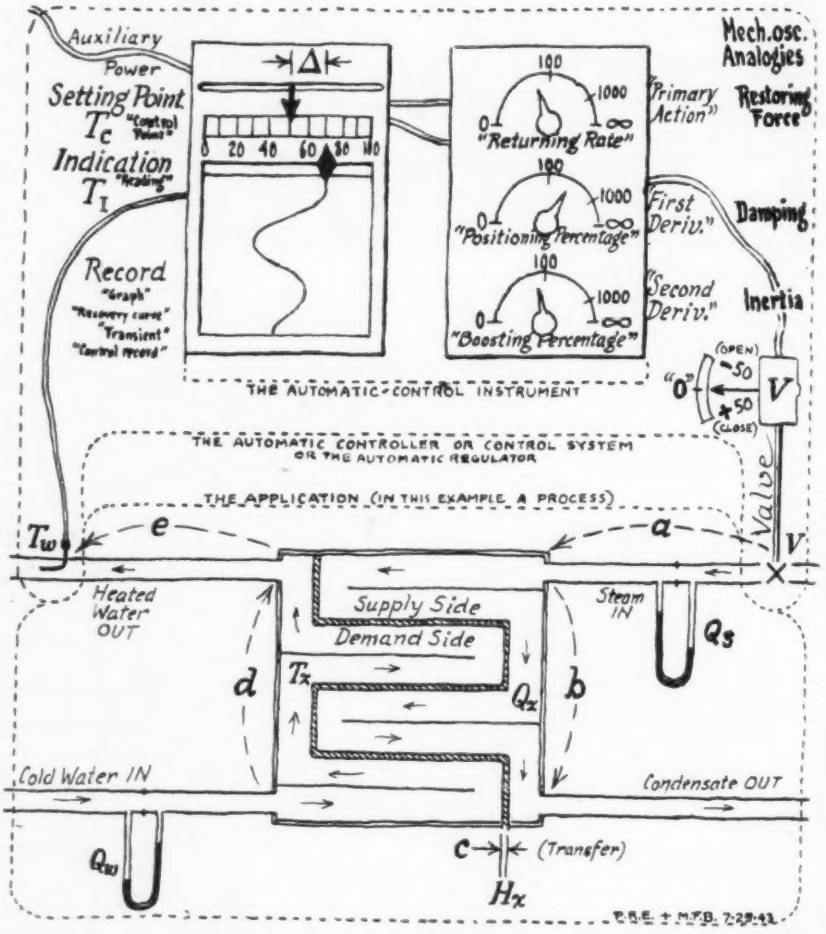


Fig. 1. A Control Circuit consisting of Automatic Controller and Application. In this example the circuit is a "Controlled Process." (Note.—From the way we have laid out the piping, etc., one solution is fairly obvious: changing the control system from a single-measuring-element controller to a two-element controller with its second thermal element continuously measuring the temperature of the *cold* water and thereby making possible an *anticipatory* mode of control. However, that would mean "changing the rules after the contest has started." Contest? Well . . . )

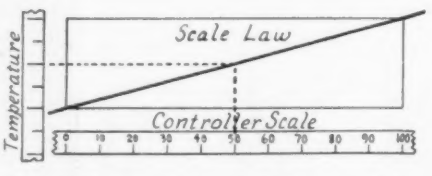


Fig. 2. No matter what particular span of the thermodynamic temperature scale the controller's scale matches, the relation is perfectly linear.

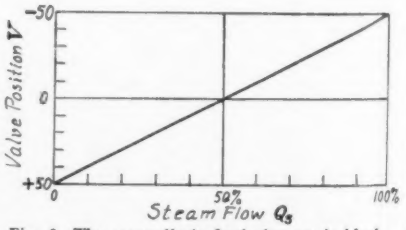


Fig. 3. The controller's final element is ideal.

$T_C$ is a "point" and not a "zone." In this particular case, moreover, the whole span of the controller's scale may be assumed to represent so small a number of degrees Centigrade or Kelvin or Fahrenheit that the dead zone, which is an essential of automatic control, is greater than a mere infinitesimal on the scale of the *controller* but nevertheless is negligible in practical calculations pertaining to the controlled *process*.

The indicating element actuates effortlessly (without drag) a relay or a plurality of relays, whereby auxiliary power operates a valve in the steam supply line. (This "assumption" is a common actuality.) The position of the valve determines the flow $Q_S$ of constant-temperature and constant-quality steam, hence the rate at which heat is transferred to the water.

It is assumed that the controlled valve is ideal in that the steam flow $Q_S$ (and hence the flow of calories) through it is a linear function of the valve opening as shown in Fig. 3.

It is assumed that the mechanism of the automatic controller is capable of acting instantaneously, so that a change in $T_W$ (any change in $T_I$ between "0" and "100") can instantly command a change in $V$ (between +50 and –50). It is further assumed that the auxiliary power is limitless and that the valve is inertialess, so that $V$ (and hence $Q_S$) can be changed instantaneously.

These assumptions, as in the case of the absence of a dead zone, can be logically justified by simply stating that the process lags are enormously greater than the control-system lags.

It is assumed that the automatic controller's mechanism includes measuring or discriminating elements (distinct from its temperature measuring system proper) which are capable of the following functions:

(1) Continuously measuring the instantaneous value of the departure;

(2) Discriminating between values of $\Delta$ above and below 50;

(3) Continuously measuring the rate of departure $d\Delta/dt$ and, of course, distinguishing its direction.

Finally, it is assumed that the automatic controller's mechanism possesses a plurality of $\Delta$ vs. $V$ and $(d\Delta/dt)$ vs. $V$ characteristics or "corrective-action characteristics" or "valve-action characteristics" or "performance characteristics" or simply *principal characteristics*, so that its mode of control is a complex mode even if not modified by application characteristics. There naturally follows the important assumption that *each* of these controller characteristics or "actions" is individually adjustable, so that THE mode of control is "fully" adjustable. (Common examples in practice, individual adjustments for throttling range and for rate of droop correction.)

In practice, the choice of the number and types of control-action characteristics determining the mode of control will depend primarily upon the various characteristics of the application and upon the at-least-partial *adjustability* of these application characteristics (which determine "controllability"), upon the desired "closeness" or "goodness" of control, upon cost, etc.

In this case, the specification of control characteristics amounts to *nothing less than the basis of the solution of the problem.* Essentially, the problem is to specify a controller which, in spite of varying inlet water temperature and in spite of application lags, will cause the heat exchanger to deliver water heated as close as possible to $T_C$ during the greatest possible number of minutes throughout the day. Not only must departures be minimized but their durations must be minimized. In mathematical language, the specific problem is to minimize the hourly (or daily) totals of the areas $\int d\Delta$, both positive and negative: to damp them out in minimum time. In plain language, therefore, the solution of the problem is to state what an ideal controller should do and why. Such a statement, of course, is essentially a description of the characteristics of the ideal controller for the two-capacity application, followed by an analysis of the interaction of controller and application, leading to a proof that the departure integrals are minimized.

Now then, Mr. Ewald, take over!

IN spite of the editor's implying that even our first draft was a "solution" we prefer to describe this article as a presentation of a theory for an ideal automatic-control circuit, particularly as applied to chemical processes. The presentation will show the resemblance of such a circuit to a forced mechanical oscillating system, thereby suggesting solutions.

In order to control the process illustrated in Fig. 1, the mechanism of the ideal automatic controller depicted in that figure should possess not less than three control-action characteristics and it need not possess more than three. Let us imagine a disturbance to have occurred, and proceed first with a study of the corrective actions.

The moment that the indicating pointer deviates from the setting-point a distance $\Delta = T_I - T_C$ the control instrument will initiate three distinct modes of motion of the controlled valve (and hence of changes in $Q_S$):

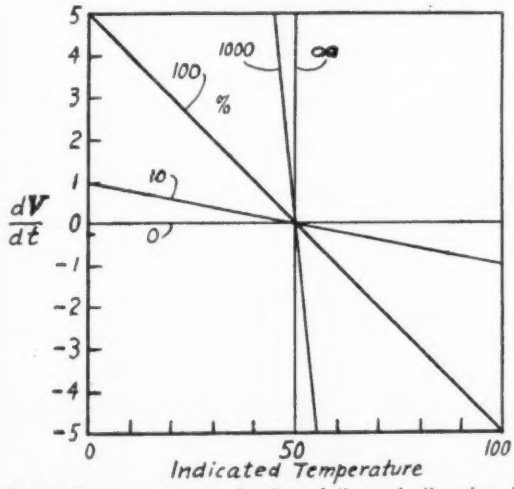


Fig. 4. Primary or proportional-speed "returning" action. Mr. Ewald's mechanical forced-oscillation analogue is the restoring force.

First, the primary or returning action will be started which MOVES THE VALVE CONTINUOUSLY to oppose the deviation until the temperature returns to the setting-point. The speed of valve travel can be made proportional to the deviation, or $-(dV/dt) = A(T_I - T_C) = A\Delta$ as shown in Fig. 4. Different slopes of the graph represent different returning speeds from the 0 slope along which the valve would not move for any deviation of temperature, to the ∞ slope along which the valve would run open or closed instantly for any deviation at all. This type of action is the fundamental of the three to be described and is the only one which will bring the temperature back to the setting-point by its own effects. It is commonly known as floating control. This action alone is usually too slow for satisfactory process control. Variants include returning speeds which are not directly proportional to the deviation, and constant returning speed. The last-mentioned type is fundamentally a "hunting control" unless a dead zone is provided.

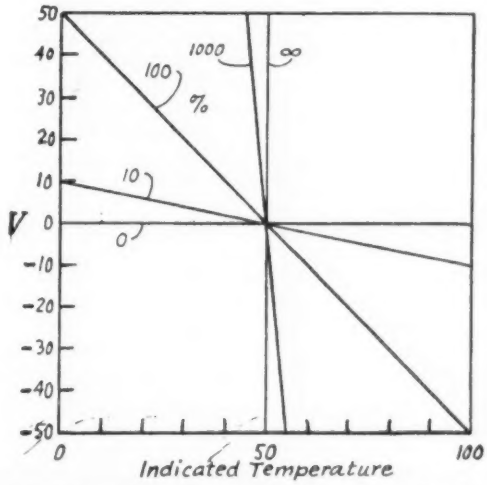


Fig. 5. "First-derivative" or positioning action. Mr. Ewald's mechanical forced-oscillation analogue is the damping.

Second, the first-derivative or positioning action consists in POSITIONING THE VALVE IN PROPORTION TO THE DEVIATION to supply more or less steam in order to oppose the deviation. The position of the valve may be expressed as

$$-V = B(T_I - T_C) = B\Delta$$

as shown in Fig. 5, or $$-\frac{dV}{dt} = B\frac{d\Delta}{dt}.$$

The different slopes of the graph represent different percentages of positioning for a given deviation from the 0 slope, along which the valve will not assume a new position for any deviation, to the ∞ slope along which the valve opens or closes completely for the smallest deviation. The ∞ slope gives us on-off control. Common names for position-

ing control are proportional and throttling control. While this mode of control is fast-acting, it is not complete in that it merely positions a valve and does not allow for any condition changes in the process. As a result, if it is set to control at a certain point and the load or supply to the process changes, it will continue to position the valve as before, but the actual control point [the equilibrium point] will not be at the intended place [setting-point]. This control deficiency is commonly called droop or load error.

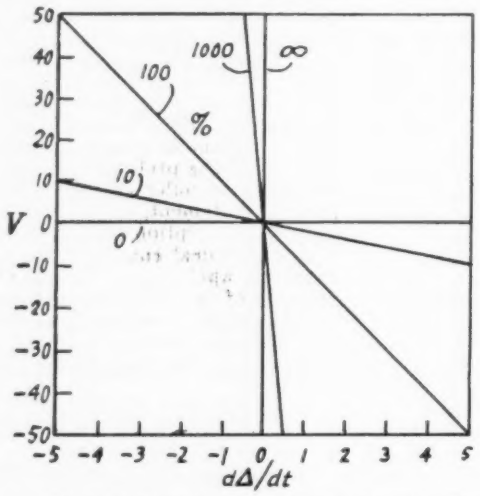


Fig. 6. "Second-derivative" or "boosting" action. Mr. Ewald's mechanical forced-oscillation analogue is the inertia.

Third, the second-derivative or boosting action consists in positioning the valve in proportion to the RATE OF DEVIATION from or toward the setting-point. The valve position may be expressed as $-V = C(d\Delta/dt)$

as shown in Fig. 6 or $$-\frac{dV}{dt} = C\frac{d^2\Delta}{dt^2}.$$

Different slopes of the graph represent different percentages of positioning for a given rate of deviation, from the 0 slope along which the rate of deviation has no effect on the valve to the ∞ slope along which the least change of temperature completely opens or closes the valve. Such action, of course, merely supplements the other two to give a boost or kick to the process to reduce the effects of sudden load changes.

It would be possible to include a fourth action to position the valve in proportion to the acceleration of the indicating pointer away from the setting-point or $-V = d^2\Delta/dt^2$, but at present such an action would be superfluous and will not be considered further.

The movement of the valve will be dependent on the three characteristics of the ideal control mechanism[1] or:

$$-\frac{dV}{dt} = A\Delta + B\frac{d\Delta}{dt} + C\frac{d^2\Delta}{dt^2}.$$

This is a complete linear differential equation and its similarity to that for a simple oscillating system is evident. Where $dV/dt = 0$ the equation is for an oscillating system with one degree of freedom. When $dV/dt = E \sin Kt$, the equation becomes that of a forced oscillating system. These systems are illustrated in Fig. 7. Bearing these facts in mind we will continue examining the process to determine if it cannot be represented as a forced oscillating system.

The quantity of steam $Q_s$ passing through the valve being a linear function of the valve opening $V$, within operating limits and under reasonably steady conditions the output temperature $T_w$ will be a linear function of $Q_s$ but with a number of time lags between the two. These lags are, as shown in Fig. 1:

(*a*) velocity-distance lag from valve to exchanger;
(*b*) supply-side capacity lag of exchanger;

(1) J. C. Peters, "Experimental Studies of Automatic Control." *Transaction A.S.M.E.*, Vol. 64, No. 3, April 1942, pages 247-253: discussion, pages 253-255.

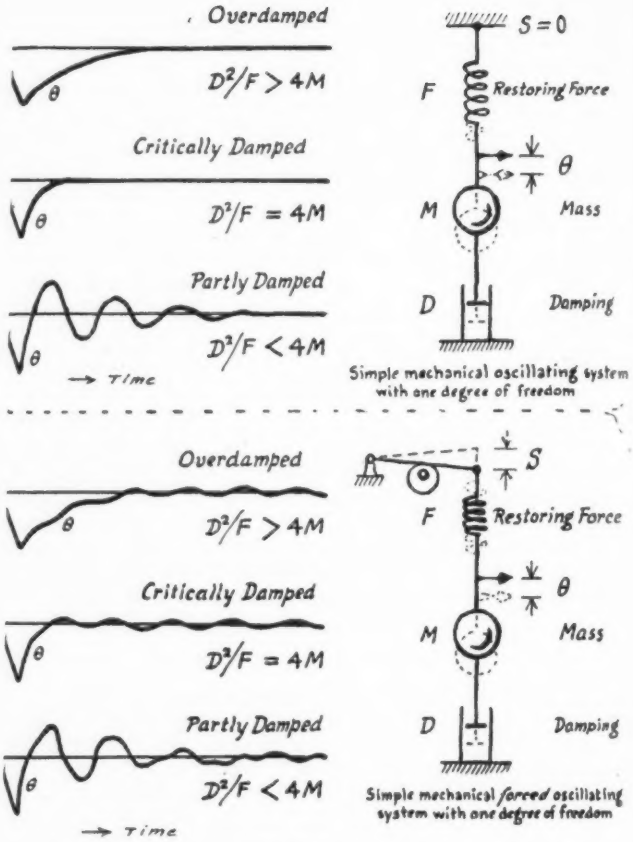


Fig. 7. Effect of disturbance on mechanical oscillating systems.

(*c*) transfer lag of exchanger;
(*d*) demand-side capacity lag of exchanger, and
(*e*) velocity-distance lag from exchanger to controller.

These lags may be added to give one overall process lag, under certain conditions as we will see later. [The controller's lags are assumed to be negligible.] Any change in valve opening will produce a change in $T_w$ but at a later time. Moreover, except when extremely slow, the change in $T_w$ will probably bear no resemblance to that at $V$ because of the capacity of the system unless $V$ is following a simple harmonic or sine wave motion. This is true because in systems having a capacity lag, any periodic disturbance tends to smooth itself out into a sine function. Thus we can see that while the velocity-distance lags will transmit any change in state but with a time lag, the capacity lags will tend to convert any periodic change in state to a simple harmonic function. Fig. 8 is an illustration of this effect.

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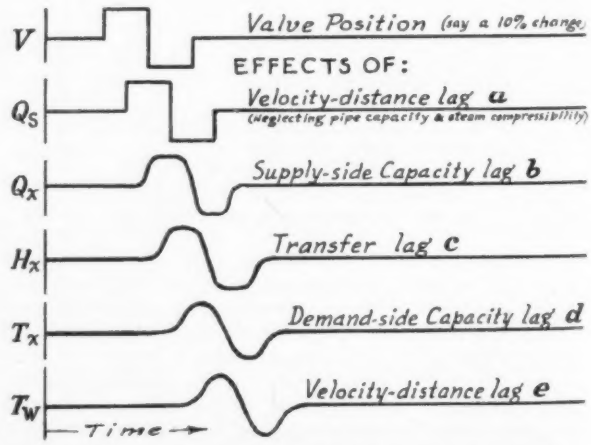
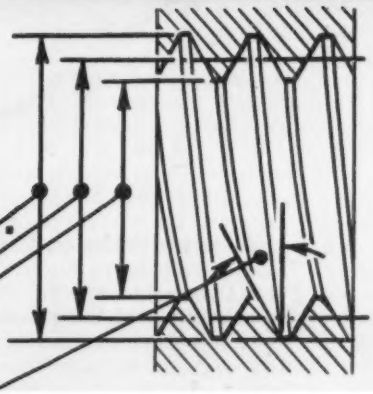



Fig. 8. Effects of the five application lags in the Fig. 1 circuit.

# Cut these quickly, cleanly and accurately . .



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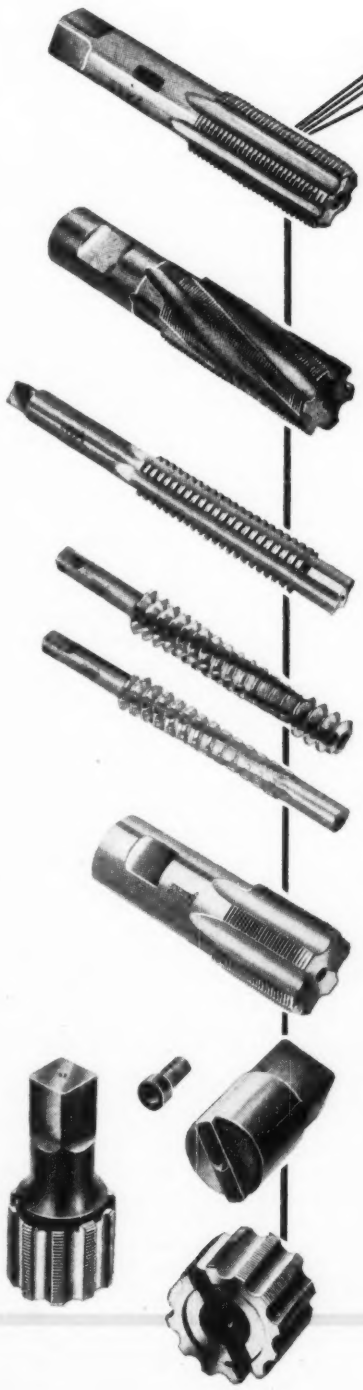

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# Oscillographic Measurements in Spot Welding Research

By ROBERT A. WYANT

Assistant Professor, Department of Metallurgy, Welding Laboratory, Rensselaer Polytechnic Institute, Troy, N. Y.

SINCE early in 1938 the Welding Laboratory of the Rensselaer Polytechnic Institute has been continuously engaged in research on the spot welding of many different metals and alloys. Spot welding, in its simplest form, consists of clamping two pieces of sheet metal between two copper electrodes and passing an electric current of sufficient strength through the pieces to fuse them together at the spot where the current is most concentrated. Oscillographic measurements have played an important part in this research and it is the purpose of this article to describe some of the apparatus and techniques employed. Much of this equipment and the methods of applying it had to be developed to meet the particular requirements of the different projects. For the degree of success achieved, much credit is due to Dr. Wendell F. Hess, Head of the Laboratory, and other members of his staff for their contributions.

In this research there is employed an electromagnetic oscillograph (Westinghouse Universal PA type) equipped with four standard vertical galvanometers and one standard horizontal galvanometer to provide a timing wave. The camera is of the drum type which was designed for either loading with roll film or exposing a single length (14″) of film or paper. The latter method is used in this work where it frequently is necessary to examine one record before another is taken. Normally this type of camera has to be removed from the oscillograph and taken to a dark room for loading and unloading. To increase the efficiency of this process a semi-portable dark room (4′ × 4′) is provided near the welding machine under investigation. The oscillograph is mounted on a table adjacent to the dark room as shown in Fig. 1. A black cloth hood is installed between an open window in the dark-room wall and the camera to permit loading and unloading of the camera without removing it from the oscillograph. Recording paper (Eastman Grade 697) is purchased in 100′ rolls, cut into 14″ lengths and stored in light-tight cans within the dark room. To increase the efficiency of processing the exposed paper a tank system is employed. The developing and fixing solutions are kept in enameled tanks, 2½″ × 8¾″ × 14″ deep, for which floating cork covers are provided. The oscillograms are suspended in the solutions by means of stainless steel clips. By this means the solutions last longer and the processing can be done more rapidly and conveniently than when the system of bottles and trays is employed. The washing is done in a tank which requires that water and drain connections be made to the dark room. While suitable illumination has been provided in the dark room, the installation of a ventilator and apparatus for drying the oscillograms would be distinct improvements.

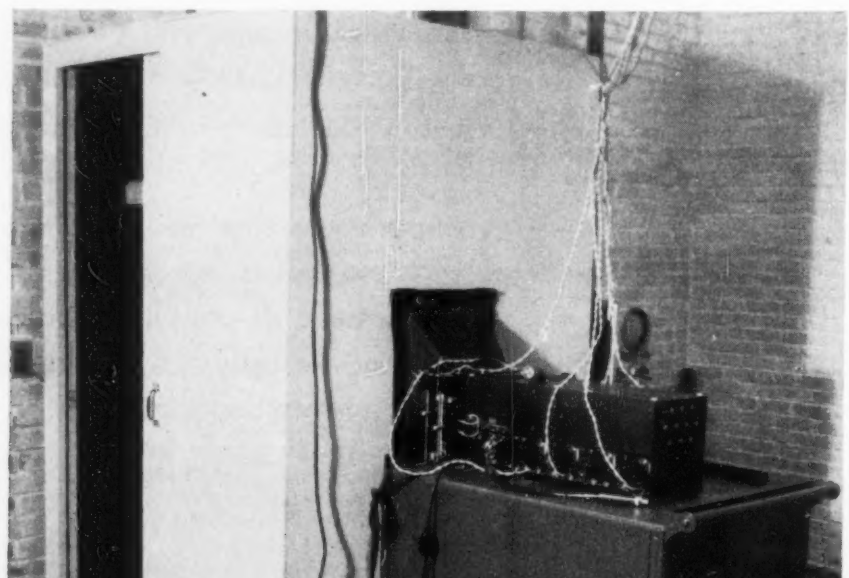

Fig. 1. Semi-portable dark room, and oscillograph with camera enclosed in black cloth hood.

Most of the oscillograms are taken at one of two camera speeds. When it is desired to make a complete record of a spot weld from the time the electrodes contact the work to the time when they leave the work, a speed of about 5″ per second is employed. When it is desired to investigate phenomena which occur only while the welding current is flowing, a speed of about 50″ per second is frequently used. The camera is synchronized with the welding machine by means of the mechanism provided on the camera for that purpose. This mechanism is so connected that it actually trips the welding machine at the proper time with respect to the rotation of the camera drum. While it is true that any inconsistency in the speed of operation of the welder will upset the synchronization, little trouble of this nature has been experienced in working with standard welding machines of different types.

In all spot-welding operations the two most important variables are welding current and electrode pressure. Fig. 2 shows the electrode arms, holders and tips of a spot welding machine. To obtain an oscillographic record of the welding current, a shunt is installed in the lower electrode holder and potential connections are provided as shown in Fig. 2. The shunt consists of a cylindrical piece of manganin 1″ long and having the same inside and outside diameters as the electrode holder. It is made with threaded bosses on each end to facilitate its assembly in the electrode holder. The shunt introduces a resistance of about 20 microhms in the secondary circuit which does not seriously affect the performance of the welder for experimental purposes. While the shunt is subjected to the same water cooling as the rest of the holder, it does heat up when welds are made at a rapid rate. This prohibits its permanent installation in production welders. The potential connections consist of two small steel knife-edge contacts which are mounted a fixed distance

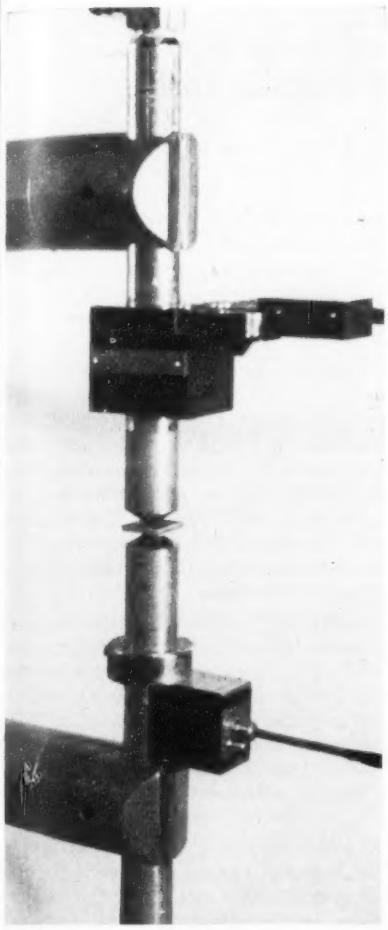

Fig. 2. Electrode assembly of spot welder: Electric strain gage in upper electrode holder; Current shunt in lower electrode holder.

apart in an insulated block which is seen in the lower part of Fig. 2. Connections are made between the knife-edge contacts and oscillograph by means of a coaxial conductor. With this equipment alternating currents up to about 75,000 amperes have been measured. When the potential connections are properly made the error due to inductive interference is negligible.[1] Equally satisfactory results are obtained with this apparatus on spot welders of the energy-storage type designed for welding the light alloys.

To obtain an oscillographic record of electrode pressure, an electric strain gage is installed in the upper electrode holder and connections are provided as shown in Fig. 2. This strain gage consists of four non-inductive windings of a fine (0.001" diam.) resistance wire, which are insulated from the holder and each other by thin paper and cement.[2] The windings are so arranged that when the electrode holder is subjected to a compressive force, two windings are subjected to compression and the others to tension. The windings in tension increase in resistance and those in compression decrease in resistance.[3] The windings are connected to form a Wheatstone bridge in such a way that the change in resistance of each arm, due to change in stress in the holder, will contribute to the unbalance of the bridge. Power is supplied to the bridge by means of an audio-frequency oscillator (1000 c.p.s.). The output of the bridge is passed through a band pass filter and an audio-frequency amplifier which is connected to the oscillograph. Auxiliary apparatus is provided for balancing the bridge at zero electrode pressure and for calibrating the circuit. The strain gage shown in Fig. 2 is constructed on a section of electrode holder 1¼" O.D. copper alloy) which has been counterbored to obtain a wall thickness of ⅛" for an axial distance of about 1⅝". This was done to increase the sensitivity of the apparatus by concentrating the stress in the wall of the holder at the point where the strain gages are mounted. This equipment has been applied to welders operating at electrode pressures to 3000 lbs.

This application of electric strain gages of the fine wire type is particularly interesting because of the fact that the gages have to function in the intense magnetic field created by the welding current. It was for this reason that it was necessary to construct special non-inductive gages instead of using those commercially available for ordinary structural purposes.[4]

Some typical oscillograms obtained with the above equipment are shown in Fig. 3. These particular oscillograms were taken on a spot welder of the electromagnetic energy-storage type designed for welding the light alloys. The pressure record consists of an envelope of the 1000-c.p.s. wave. Other investigators have developed similar equipment in which this wave is demodulated to give an ordinary trace on the oscillogram.[5] Oscillograms of this type have been extremely useful in studying the effects of friction and inertia in resistance welding machines, variations in pressure on the weld during its formation, and synchronization of welding current with electrode pressure.

Spot welding is one of the most fundamental of the electric resistance welding processes which depend upon the Joule effect, $H = I^2RT$, for the generation of heat. The total resistance involved in spot welding consists of the body resistance of the metal between the electrodes plus the sum of the sheet-to-sheet and electrode-to-sheet contact resistances. All of these resistances vary with temperature and, therefore, with time while a weld is being made. The oscillograph has been an extremely useful tool in studying these resistances and their variations during the actual welding process.[6] To accomplish this the oscillograph galvanometers are connected so as to simultaneously record the voltage drops across the secondary

*Concluded on page 510*

(1) W. F. Hess, R. A. Wyant and A. Muller, "The Measurement of Spot-Welding Current." *Electrical Engineering*, June 1940, *Transactions*, pages 349-250.

(2) W. F. Hess and R. A. Wyant, "A Method of Studying the Effects of Friction and Inertia in Resistance Welding Machines." *Welding Journal*, October 1940, *Research Supplement*, pages 433-440.

(3) A. V. DeForest and H. Leaderman, "Development of Electric Strain Gages." *N.A.C.A. Technical Note No. 744*, January 1940.

(4) Descriptive Literature on the SR-4 Series of Electric Strain Gages and Their Applications, Baldwin Southwark Division, The Baldwin Locomotive Works, Philadelphia, Pa.

(5) H. Wolfe and R. W. Powel, "Device for Measuring Tip Force and Current in Spot Welding." *Welding Journal*, June 1942, *Research Supplement*, pages 293-296.

(6) W. F. Hess and R. A. Wyant, "Further Studies of the Spot Welding of Low Carbon and Stainless Steels." *Welding Journal*, October 1939, *Research Supplement*, pages 340-354.

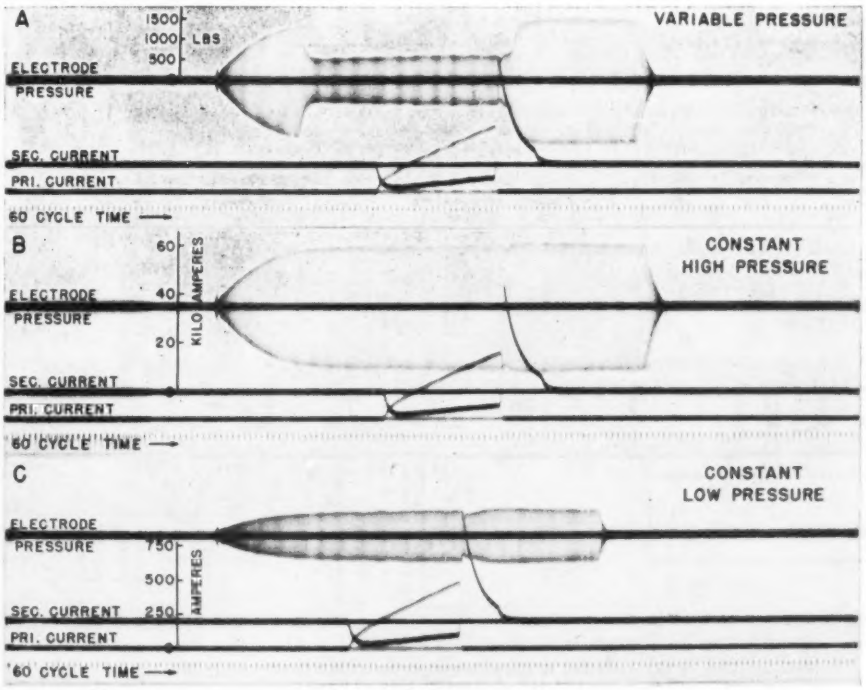


Fig. 3. Oscillographic records of electrode pressure, primary current and secondary current in a spot welder of the electromagnetic energy-storage type.

# ELECTRON TUBES

## Their Principles and Their Instrumentation Applications

By ANDREW W. KRAMER

**Managing Editor, *Power Plant Engineering*, Chicago, Ill.**

### CHAPTER V

### AMPLIFIER APPLICATIONS OF THE TRIODE

The enormous importance of the thermionic tube in the world today is the consequence, not so much of its ability to function as an amplifier, as it is of the degree to which its amplifying properties can be extended; in other words, its sensitivity. The idea of an electrical amplifier was not new with the triode. Nearly all relays are amplifiers to some extent; practically every magnetically controlled contactor is an amplifier. Long before the development of electron tubes, the magnetic telegraph relay or "repeater" had functioned successfully on long telegraph lines. The telegraph relay is nothing more than a device to amplify weak telegraph signals at the end of a long circuit so that they can operate a sounder requiring a relatively large amount of energy. Its principle is exactly that of the magnetic relay which was shown in Fig. 20A—a telegraph sounder taking the place of the bell, however.

The success of this method of repeating or amplifying on telegraph lines led early telephone engineers to seek a similar device that might be used on telephone lines. The comparatively weak voice currents involved in wire telephony are rapidly attenuated (weakened) in their passage over long lines. This attenuation limited telephony to short distances. Many forms of amplifiers or repeaters were produced but most of them were ineffective.

The simple idea incorporated in these devices parallels that used in the telegraph repeater. Fundamentally, it involves merely the placing of a microphone contact in operative relationship with the diaphragm of a telephone receiver, as shown in Fig. 29. It seemed plausible that the feeble currents received by the telephone receiver would, by virtue of the delicate action of the microphone, be able to produce comparatively large variations of current in the local microphone circuit and that in this way the amplified voice currents could be sent on to a distant receiving station. If this scheme could be made to work in one instance, there was, of course, no reason why a series of such elements could not be set up to transmit voice currents almost any distance.

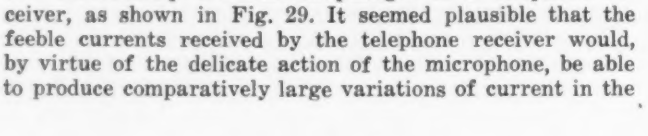


Fig. 29. The idea involved in the early telephone repeater is quite simple. It consists, essentially, in an arrangement in which the diaphragm of a telephone receiver is placed in operative relation with a carbon transmitter unit so that the received impulses actuate the transmitter directly.

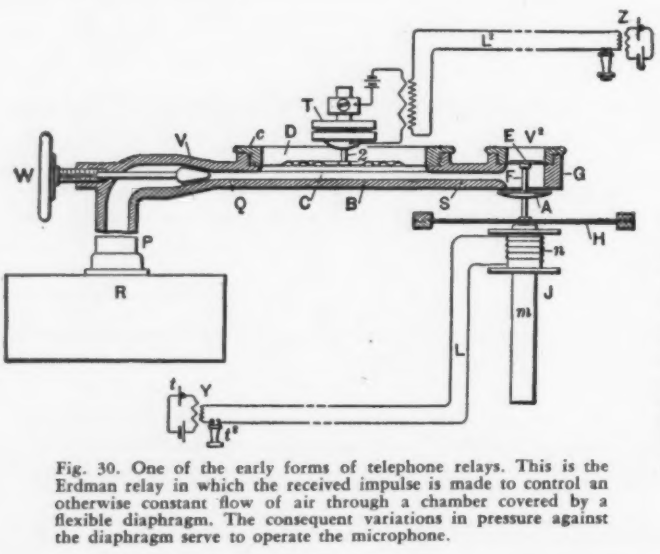


Fig. 30. One of the early forms of telephone relays. This is the Erdman relay in which the received impulse is made to control an otherwise constant flow of air through a chamber covered by a flexible diaphragm. The consequent variations in pressure against the diaphragm serve to operate the microphone.

As a matter of fact, however, no gain in volume of transmission was ever commercially effected by this method. Many forms were produced, some quite complex and ingenious as shown by the one in Fig. 30. In this particular version, the receiver diaphragm $H$ operates a balanced valve $V^2$ which varies the flow of an otherwise constant stream of air flowing through chamber $C$. The resulting changes in pressure are communicated to the transmitter button $T$ through a flexible diaphragm $D$. Other types of repeaters operated entirely in vacuum.

Nearly all of these electromagnetic-mechanical repeaters could be made to work perfectly on ordinary telephone lines but none of them had the ability to transmit speech between two distant points any better than, or quite as well as, could be done without the use of the relay at all. The amount of energy received by the electromagnet of the relay is so exceedingly small that it cannot be made to produce the desired mechanical effect upon the microphone contact.

All this is merely by way of introduction. It has nothing to do with electron tubes except to serve as a basis for comparison—to show how marvelously sensitive the electron tube is compared to these early attempts to produce telephone amplifiers: all these early telephone repeaters have been consigned to oblivion by the development of a simple little tube containing a heated cathode and a few other electrodes. The three-electrode tube described in the preceding chapter gave the telephone engineer a telephone repeater so inconceivably sensitive, so astonishing in reliability and performance that almost overnight the limits of telephone transmission were extended to the farthest corners of the earth. Let us consider this specific application of the three-electrode tube amplifier, for it is an excellent introduction to industrial measurement and control applications.

To overcome, or rather to compensate for the attenuating effect of the resistance or impedance of the line on the current, electron tube amplifiers are placed in the circuit at more or less regular intervals. These amplifiers, or repeaters as they are called, are exactly like the amplifier described in the preceding chapter. The principle of operation is illustrated in Fig. 31 which shows a single repeater in a

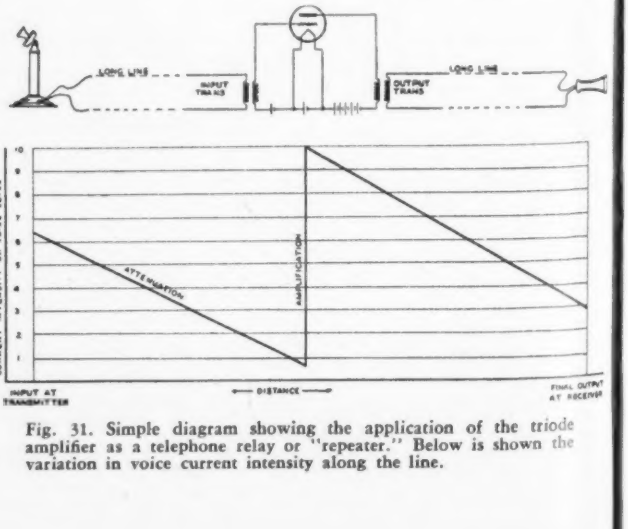


Fig. 31. Simple diagram showing the application of the triode amplifier as a telephone relay or "repeater." Below is shown the variation in voice current intensity along the line.

telephone line, and below it a graph of the intensity of the voice current along the line. As indicated by the scale at left, the voice level at the transmitter is assumed to be about 6.5 units. As this voice current travels over the long line, its intensity diminishes steadily with increasing distance until, at the input to the repeater station which is located at the halfway point, it has an intensity of about 0.5 unit, an amount (it can be assumed) too small for actuating a telephone receiver. At the repeater station, however, the electron-tube amplifier amplifies this weak voice current to 10 units, to a value even higher than the original output at the transmitter. This amplified current, which of course preserves every detail of the voice variation, is now sent out over a further stretch of line where again it suffers attenuation but arrives at the receiver with an intensity of almost three units, sufficient to actuate the telephone receiver.

This probably is the most important application of the electron-tube amplifier that can be cited. It is used on every long telephone line in the world. Fig. 32 shows how the voice current is amplified sixteen times in this manner on the New York-San Francisco telephone line. The intensity of the voice current can be controlled to any desired extent, the received current at New York often being greater than when it left San Francisco. This is in accord with the law of the conservation of energy for, at each repeater station, the gain in intensity is effected by the addition of energy supplied from local batteries or generators.

The arithmetic of amplification may be of interest. On the San Francisco-Havana line, for example, with the transmitter delivering 1000 microwatts at San Francisco, the power received at Havana at the end of the 5500-mile circuit in commercial practice is about 25 microwatts. If there were no intermediate amplifiers, and assuming that the line could carry unlimited power without burning up, it would be necessary, in order to deliver 25 microwatts at Havana, that power sufficient to light an ordinary 60-watt incandescent lamp be flowing in the circuit at some point in North Carolina. At Philadelphia the power in the line would be 5 kw. A little east of Denver the line would be carrying the equivalent of all the electrical and mechanical power generated in the world (enough to light 20 billion electric lamps). This is about 1/200,000 of the power which is received by the earth from the sun, yet at Sacramento all of this power (200,000 times all the power generated on earth) would have to be flowing in the line to produce 25 microwatts at Havana.*

So much for the telephone repeater. Our reason for considering it in such detail is that it is an extremely important application of the electron-tube amplifier, one in which its capabilities have been demonstrated in thirty years of increasing use, and which has led to many applications in industrial instrumentation.

*H. S. Osborne. "Telephone Transmission Over Long Lines." *Transactions A.I.E.E.*, Vol. 42, page 984.

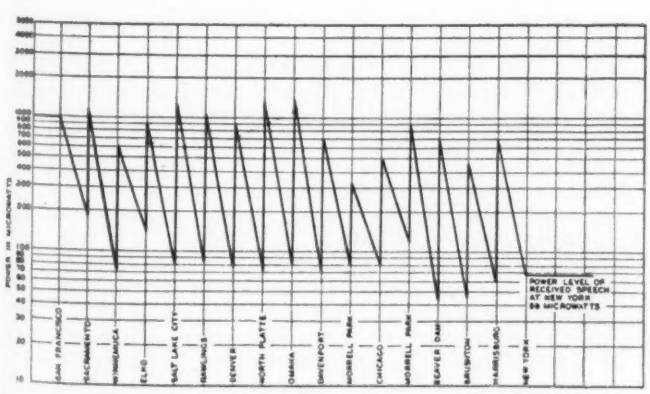


Fig. 32. Power levels of the San Francisco-New York long distance telephone line, showing the effect of the repeaters. With 1000 microwatts input at San Francisco, the voice current power level drops so slightly under 200 microwatts at Sacramento. Here the current is amplified by vacuum tube repeaters to a value of over 1000 microwatts. This new high level falls to 70 microwatts by the time it reaches Winnemuca where it is again amplified. Thus the voice current is amplified successively 15 times before it reaches New York City.

### *The Grid Draws No Electrons*

It is worth while here to emphasize one point. The superiority of the electron-tube amplifier over all other forms of electrical amplifiers lies in the fact that *the grid draws no electrons* when it is maintained at a proper negative potential. The significance of this statement must be fully understood because it explains the tube's marvelous sensitivity. Although the gird draws no electrons when maintained at a negative potential, variations in this negative potential *do* cause variation in the plate current. Hence, it is possible for a voltage representing practically no energy to control a relatively large space current and to develop a corresponding quantity of electrical energy in the plate circuit. Another great advantage of the electron-tube amplifier is its ability to amplify frequencies up to all but the very highest used in radio communication, i.e., up to well over a hundred million cycles per second. Finally, by using two or more tubes in series or "cascade," almost any degree of amplification can be obtained.

The action of the triode amplifier has been considered in some detail but to show more clearly that the grid draws no electrons when maintained at a negative potential, the two diagrams, A and B in Fig. 33, have been drawn. These, of course, are purely hypothetical but they attempt to show the paths of electrons under two different values of negative grid potential, i.e., –3 volts and –9 volts. At A, which shows conditions in the tube at the instant the grid potential is, say, –3 volts (with respect to the cathode), nearly

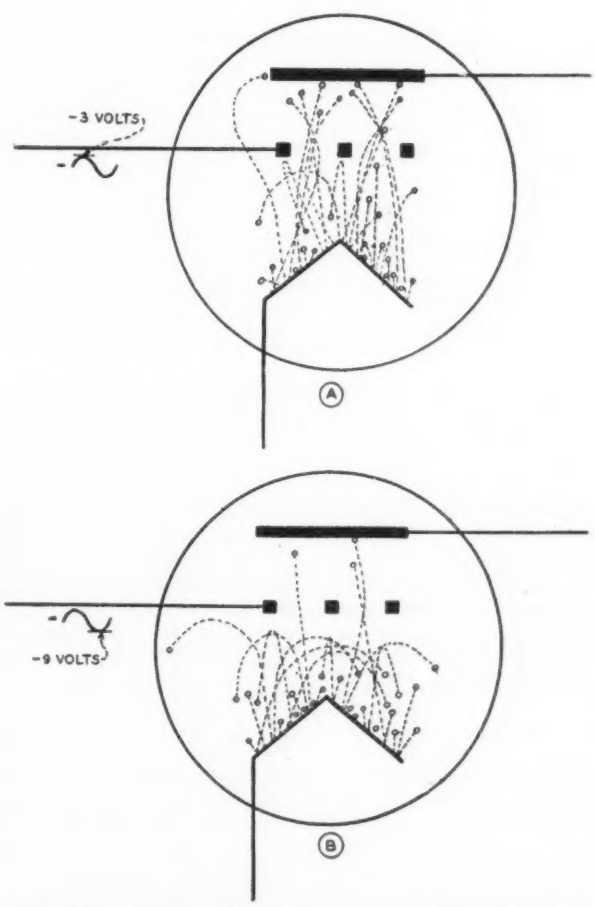


Fig. 33. Two diagrams which attempt to show the effect of varying negative potentials on the grid upon the cathode-anode current. "A" represents an instantaneous picture when the grid potential is 3 volts negative. Although the grid repels the electrons, most of them get through the grid and reach the plate. At "B," however, where the negative grid potential is 9 volts, the repelling influence of the grid is much stronger and few electrons reach the plate.

all of the electrons emitted by the cathode reach the plate. Their paths are curved because of the repulsive influence of the negatively-charged grid wires, but this negative charge is not sufficient to prevent them from getting through the openings of the grid.

At B, a different condition prevails. Here, conditions are depicted at the instant when the grid potential has swung to –9 volts. The repulsive influence of the grid is now much greater than it was in the first instance; as a consequence, few electrons manage to get through to the plate; most of them are turned back towards the cathode. This condition represents low plate current. Case A represents high plate current. In the diagram, for purposes of illustration, the electrons travel relatively long paths before they are turned back to the cathode by the grid action. Actually they are turned back close to the cathode.

This action was explained in the preceding chapter but it should be noted that in neither of the two cases depicted in Fig. 33 do any electrons flow to the grid—the grid repels them all. This is the important fact to remember, for, since no electrons are captured by the grid, no current flows in the grid circuit, and since no current flows in the grid circuit, practically no energy is necessary to effect the control of the plate current we have described.

We say no current flows in the grid circuit. From an absolute standpoint this is not strictly true. If the grid undergoes variation in negative potential, there must be some surging back and forth of electrons between the ends of the "open" grid circuit. This, of course, constitutes a current and requires energy but in practice this energy is so small that it is negligible. Indeed, in some electron tubes this grid current is expressed not in amperes or milliamperes, but in terms of electrons per second!

In the FP-54 tube* for example, the sensitivity is so great that with suitable circuits a current of $10^{-18}$ amperes can be measured. In terms of electrons, this current represents a flow of approximately six electrons per second! This, of course, is unusual but compared to any other form of electrical device, even the ordinary electron tube used in commercial applications, is extremely sensitive. It must be clearly understood, however, that the condition of zero grid current holds only as long as the grid is maintained negative with respect to the cathode. The instant the grid becomes positive (as it does in some applications) it attracts electrons and current will flow in the grid circuit. In all instances, however, this grid current is extremely small compared to the anode current. The grid in all cases (whether positive or negative) exercises control over the anode current.

From the foregoing, it should be clear that the electron-tube amplifier is essentially a device for controlling the power from a local battery by means of small (infinitesimal) voltages applied to the grid. This process of amplification is, of course, perfectly consistent with the law of the conservation of energy; it involves no mysterious gain in power nor any other process that cannot easily be explained. The amplified output of one tube can be applied to the input of a succeeding tube and the amplified output of this tube in turn can be applied to still another tube and so on until almost any desired degree of amplification is obtained. In each stage, as shown in Fig. 34, a local battery or other source of power supplies the necessary additional energy.

### *Voltage Amplification*

The electron tube can be used as an amplifier to accomplish different purposes; it may be used to amplify voltage, or current or power, whichever is necessary. These different functions are obtained largely by the design of the load into which the tube operates. In the preceding chapter, for example, brief reference was made to the effect of a load resistance in the plate circuit—that it caused the tube to function as a "voltage" amplifier.

*The FP-54 is a specially-designed high-vacuum electron tube in which a special effort has been made to reduce all losses to a minimum.

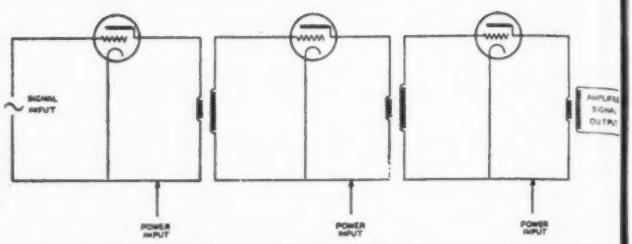

Fig. 34. Simplified diagram showing amplifiers connected in cascade.

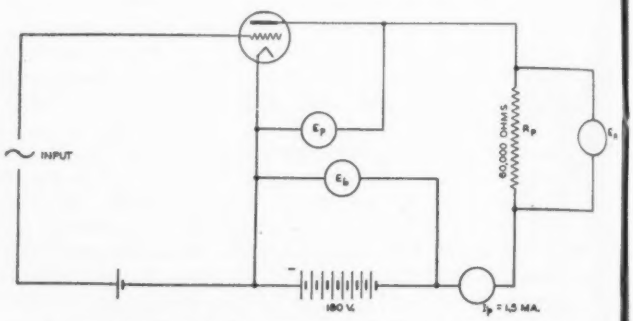

Fig. 35. Amplifier circuit showing instruments to measure currents and voltages at various points.

A specific example may explain this more effectively. In the circuit shown in Fig. 35, which is a conventional amplifier circuit with instruments included to measure voltage and current at required points, a load resistance of 60,000 ohms is included in the plate circuit. Assuming a plate current of, say, 1.5 milliamperes, the voltage drop across this resistance is given by Ohm's Law:

$$E_R = I_p \times R_p$$
$$= 0.0015 \times 60{,}000$$
$$= 90 \text{ volts.}$$

Since there is a drop of 90 volts across the resistance $R_p$ and since the battery voltage is 180, it is evident that the voltage $E_p$ across the plate-cathode is $E_b - E_R$ or $180 - 90 = 90$ volts.

Suppose, now, that as a result of varying the grid voltage 1 volt the plate current becomes 2 milliamperes. The corresponding voltage drop across the resistance $R_p$ now becomes $0.002 \times 60{,}000 = 120$ volts, a change of 30 volts. Since a change of 1 volt in the grid circuit thus produces a change of 30 volts in the plate circuit, we have an actual voltage amplification of 30.

With the same current and voltage conditions, if the resistance $R_p$ had been made 80,000 ohms instead of 60,000, the voltage change would have been 40 volts. Thus it appears that the greater the load resistance the greater the amount of voltage amplification. With infinite resistance the voltage amplification would be a maximum, but, of course, it is impossible to obtain this condition. In practice, as the resistance is increased the potential drop across it is so great that in order to impress a sufficiently high potential between the plate and the filament of the tube, and to obtain appreciable current, it is necessary to use an extraordinarily high battery voltage, which is generally undesirable in practice and frequently difficult to obtain. Accordingly, other methods are used but these will not be discussed at present. Of importance here is the fact that the function which the tube fulfills is determined by the resistance of the load circuit. In general, when a tube is required to amplify voltage, it works into a high-resistance load.

When current is to be amplified, as might be expected, the tube works into a low resistance. Similarly, a power amplifier requires a medium load resistance, usually on the order of a few thousand ohms.

These separate functions of the thermionic tube will be considered in detail in subsequent chapters.

*To be continued*

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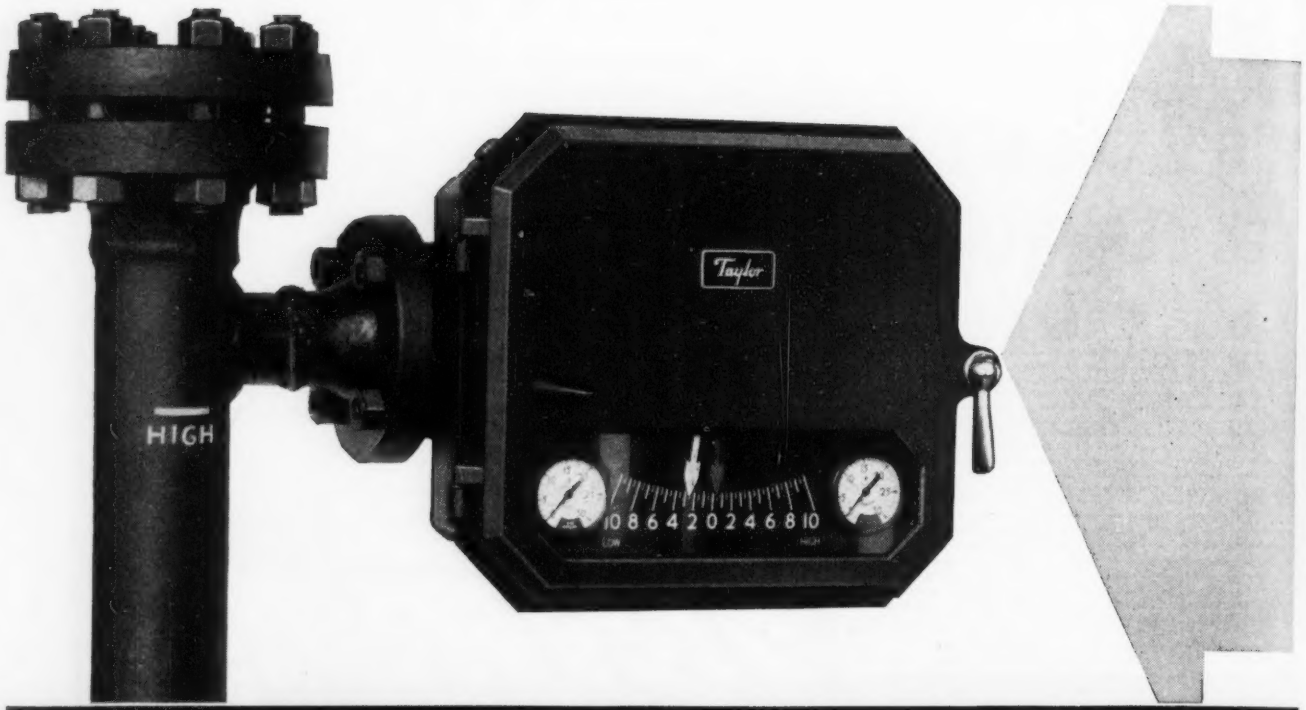


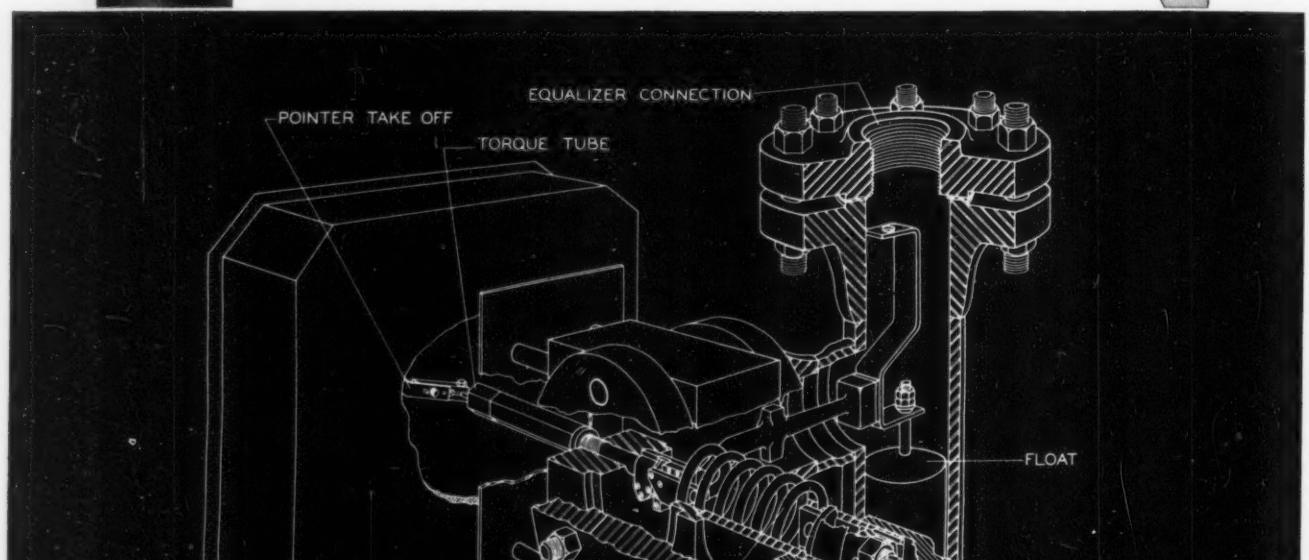

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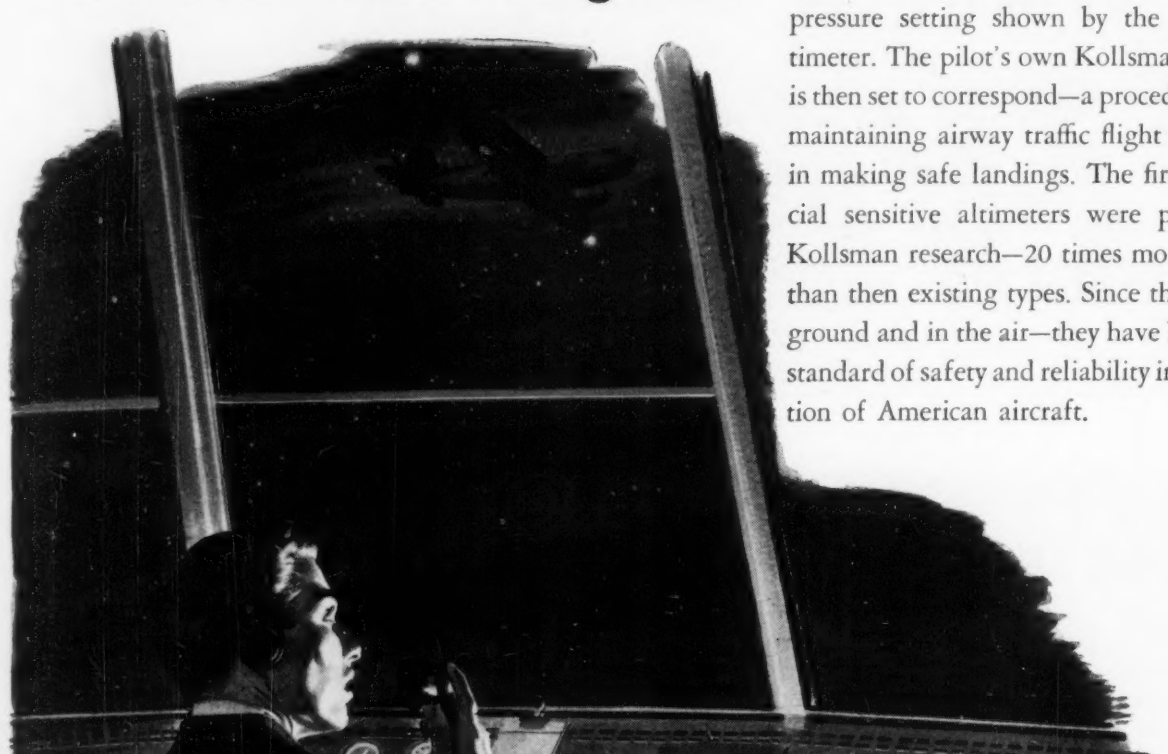

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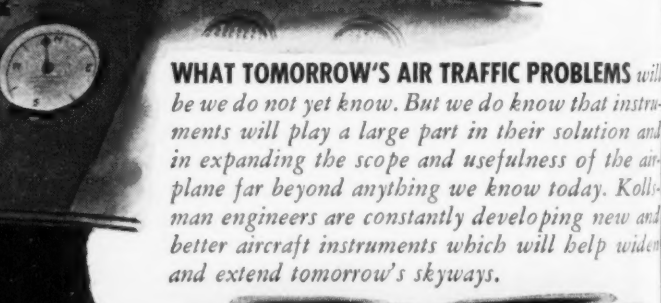

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Vol. II, No. 8 GUEST EDITOR, RAY J. STEPHAN AUGUST 1943

# LEADERSHIP

*Editorial by* **RAY J. STEPHAN,** *Guest Editor*

*Administrator, Pioneer Instrument Service School, Philadelphia, Pa.*

WE have heard a great deal about the training of trainees, the educating of students and the upgrading of employees, but how about instructing instructors and instilling qualities of leadership into our leaders, both instructors and foremen? Not that instructors and foremen are not doing a splendid job in many instances. But there is a "span" in many an instructor's and foreman's required range of abilities that is often overlooked or neglected by the individual concerned.

Let's divide the leader's responsibility to his men into two very broad, arbitrary categories: 1. His ability to DO something: his trade or skill; 2. His ability or capacity to BE somebody: his set of personal habits or characteristics.

It remains, in my opinion, one of the great paradoxes of our day and age that our schools stress technical data with utter abandon, which is, in itself, a fine thing. But, where is the stress on the other important aspect of the complete leader?

I would raise the question, "Isn't there more to the job of leadership, foreman or instructor, than merely the imparting of a skill?" Isn't the question of attitude of possibly equal importance? Doesn't leadership or instruction make gains as much by "inspiration" as by "perspiration"? And doesn't "inspiration" hinge on the development of the leader as a person, the respect he commands and the example he sets in other aspects of the job aside from the actual "work" involved?

Born Sept. 27, 1909, at Alameda, Calif., Stephan lived in Chicago from 1914 to 1926, when he returned to California and became actively interested in aviation. First he took lessons in flying, then scientifically studied the building of model aircraft. He developed quite a business; he built and sold some 400 scale models of all sizes and types, over a period of 5 years. In 1932 he used his profits to take the Master Mechanic course at the Boeing School of Aeronautics. He graduated in 1933 as the school's first major in aircraft instruments; and took a position as an instrument service mechanic with United Airlines at Cheyenne, Wyoming, where work was accomplished on both the old and the new ships. The Boeing 40's and 80 A's were on their way out and the good old Boeing 247's on their way in. After about 1½ years on aircraft instrument service, he was transferred to the U.A.L. Instrument Repair Shop. One year later, in 1935, he was transferred to Boeing School to establish a new Instrument Shop and Laboratory course. He spent seven years at the Boeing School, developing their Instrument Department. A few months after Pearl Harbor it became necessary to close commercial operations at Boeing School. In August 1942 Stephan was employed by the Pioneer Division of the Bendix Aviation Corp. for the purpose of establishing an aircraft instrument Service School. At present, this school is concerned almost entirely with training Army, Navy and Marine personnel in both the servicing and the repair of aircraft instruments.

It would be interesting to have a poll taken by students and employees in, say, just the instrument schools and shops throughout the country, and see just how we leaders stand. Some of the more important questions which could be part of the poll would read something like this:

MY FOREMAN OR INSTRUCTOR—

1. Is he enthusiastic? *Or, is he always flat and blasé or, even worse, "neutral"?*

2. Is he pleasant yet sincere? *Or, is he a hand-shaker lacking in sincerity?*

3. Is he dependable: when he says he'll do something does he do it? *Or, does he give a reason for not having done it?*

4. When troubles brew does he put himself in my boots and look at it from my point of view? *Or, does he only have his "own" viewpoints?*

5. Does he deal with me with consistency? *Or, does his treatment of me vary widely with how he feels?*

6. Does he deal impartially with me and my fellows? *Or does he play favorites?*

7. Does he notice the little improvements I make so lovingly, the little primpings? *Or, does he just look past these little "details" and see only the "big, important" things.*

8. Does he praise work well *done? Or, does he only give me hell when things go wrong and ignore my occasional well-done task?*

9. Does he inspire my confidence? *Or, do I often have to ask myself: "Is this a man or a tool of a sinister clique?"*

10. When a really important issue is at stake, does he fight for me? *Or, does he soft-pedal the issue and leave me holding the bag?*

11. Is he frank and straightforward in his dealings? *Or, does he say one thing and mean the opposite? Does he tell me one thing and the superintendent another thing?*

12. Is he pretty well organized most of the time? *Or, does he remind me generally of a spoiled young person — here, there, everywhere?*

13. If given a free choice in the matter, would I choose to work under this man, my instructor or foreman? *Or, would I take another most readily and say, "Thank God"?*

The above are just popular everyday topics discussed amongst students and employees everywhere and I wonder if it wouldn't help—*really* help—the War Effort just about as much as our learning of a new overhaul procedure or some new shop wrinkle, if we were to start to work on some of these very things.

I wonder if it wouldn't be just about as big a thing as we could do both toward getting the War over sooner and keep-

ing the Peace longer if we who are supposed to be leaders would start right in on doing some genuine, intelligent *leading*.

For a parting thought along this line, what do you think of the following excerpt taken from "Arrows and Driftwood"?:

"To live in the temper and spirit of a learner, open-minded, unwarped in judgment, free as far as light permits from delusions, eager to explore and inquire, quick to give up a confuted idea and so gain a higher outlook, striving steadily to improve and to grow—these are the watchwords of the intellectual life."

# A Note of Appreciation to Instrument Men

**By Captain ORVAL M. KLOSE, Army Air Force**
**Director of Ground Training, 20th Ferrying Group, Nashville, Tenn.**

NOT being an instrument man myself, there is little that I could say that would add anything to the technical knowledge of that fraternity of quiet, competent and precise specialists whom we know as "instrument men" and to whom we run whenever some of the super-gadgets that do our thinking for us have nervous breakdowns. However, as one who during recent years has had ample opportunity to appreciate the part played by instruments in making possible the regular, efficient and safe operation of aircraft over long distances in all kinds of weather and in all parts of the world, I welcome this opportunity to pay my respects to the men to whose inventiveness, ingenuity and workmanship I and many others are truly indebted for the safety of our lives and the success of the missions entrusted to us.

As a ferrying navigator, I have flown over 250,000 miles during the past year and a half (that's farther than from here to the moon) and with every hop—many of which were over two thousand miles in length — over oceans, jungles and deserts, my respect for instruments and the men who make them and keep them ticking has increased.

It is hardly necessary to point out that if compasses, airspeed indicators, altimeters, turn-and-bank indicators, directional gyros, vertical speed indicators, direction-finding radio devices and the like were removed from aircraft, a pilot would be forced back to the technique of "flying by the seat of his pants." While this admirable but primitive instrument is an aid not to be dismissed lightly and may even be considered as a prime qualification for a good pilot, it is still notably inadequate under sustained circumstances of reduced visibility, extreme turbulence and allied conditions. It is in weather such as this that the more precise, if comparatively artificial, instruments become indispensable. The fact that the term "instrument weather" has become standard in referring to the worst type of weather conditions for flying is itself an indication of the part played by instruments in modern air operations.

Of course, not all aircraft instruments are new and novel, although the reliability and accuracy of the service performed by even the most commonplace is a never-failing source of intrigue and—I may say, heartfelt gratification—to those who depend on them to bring them home from across one or two thousand miles of water or wilderness.

The magnetic compass, for instance, is almost as old as the hills around which it guides us. However, to one who has crossed a few thousand miles of cold wet ocean with one of these little handfuls of magnets as his principal guide, it is still a magnificent and awesome object and the flying man experiences a new respect for the puttering Chinese instrument experimentalist who, several centuries ago, "wasted good time" developing this curious gadget which would sometimes guide through the sky flying machines that neither he nor anyone else had ever seen or even dreamed of.

The aneroid altimeter is another instrument that is neither new nor strange. Developed first as a barometer, it grew into a measurer of altitudes merely through the process of having the list of air-pressures on its face replaced by one of the corresponding heights above sea-level in the earth's atmosphere. Of course, it has been doctored up with an adjusting knob which, when properly set, automatically compensates for any existing abnormal atmospheric pressure conditions but then, it is still essentially the same old gadget. However, to the navigator or pilot who knows that that ten-thousand-foot rock is a half-mile below him rather than possibly the same distance dead ahead, and who knows he can trust the altimeter that tells him so, it is a mighty fine little gadget.

Of course, there are numerous other gages and indicators and the like that were household commonplaces before the flying machine was built and were merely streamlined and dressed up a little before being adapted to aeronautical usage, but in addition to these standard articles there is quite a galaxy of new and unique instruments that have been developed in the past two or three decades solely in response to the needs and demands of the expanding transport industry. It is in this latter field that the resourcefulness and ingenuity of instrument men have had most opportunity for expression and it is here that they have made their most remarkable showing.

One of the most remarkable, as well as the most valuable, of modern aircraft instruments is the radio direction-finder, the instrument which enables a pilot or aerial navigator to determine his direction from any radio station which he can tune in on his receiving equipment. Using the more primitive form of this instrument, known as a "radio compass," a pilot can point his plane toward a radio station at his destination and keep it pointed that way until he arrives there. For a pilot flying through a solid overcast with no ground visible, or across a stretch of open water, this is a comforting arrangement.

Of course, this sort of thing was the answer to the most pressing problem of pilots who had occasion to fly "blind" at certain times. There had been a spontaneous and continuous yearning for such an invention ever since the first pilot got himself lost at night or in a fog or over unfamiliar country. It merely remained for someone who had noticed that an antenna in the form of a circular loop received radio waves better from some directions than from others to tie certain ideas together along with certain wires and gadgets and the pilot's prayer was answered. Now, no matter how badly he gets himself lost, he can always get home just by turning on his radio. Thus developed the radio compass and "homing."

It did not take pilots long, however, to ask for something else. They could always tell whether or not they were headed for home, but they wanted to know also how far away from home they were. So, the instrument man put their antenna loops on a swivel and hooked them up with a crank so the pilots could rotate the loops in any direction during the flight. With this arrangement a pilot could not only tell when he was headed toward a particular station but he could also find his direction from any station in the vicinity and, with this knowledge, he could deduce his exact position, even though he might be flying through a solid cloud, in the middle of a dark night, over country he had never seen before. Not bad.

No, that wasn't bad at all. But, if you know pilots, it will be no revelation to you that they are never satisfied, no matter how much labor-saving and worry-saving equip-

---

Captain Klose is a former instructor at Boeing school covering mathematics and navigation. He flew with Pan-American air ferries for over a year. —R.J.S.

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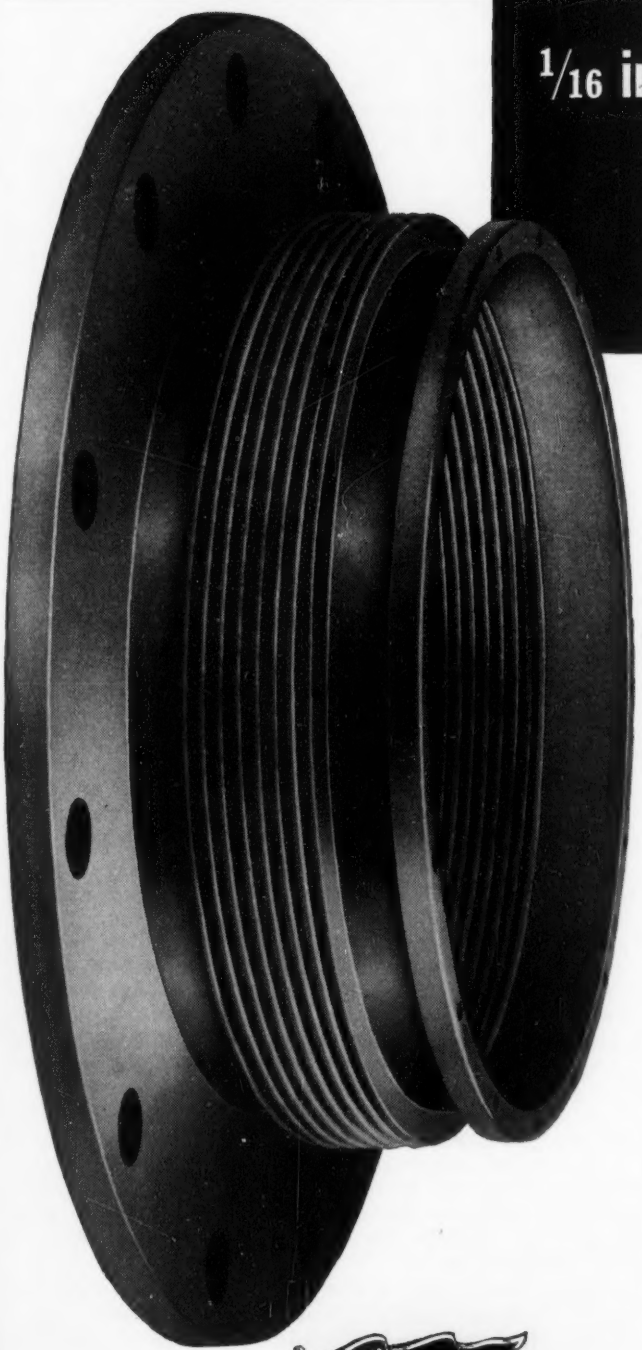

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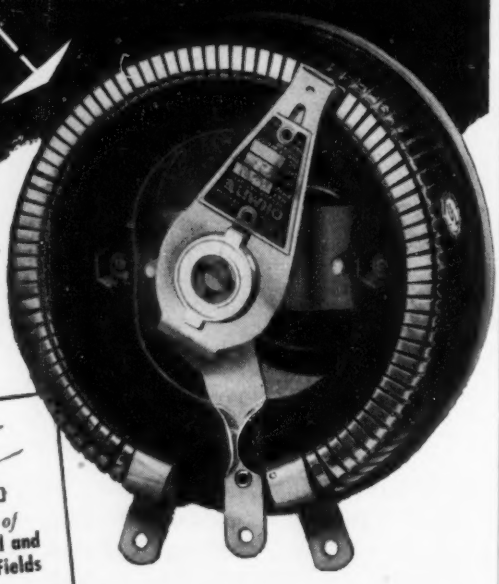

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ment they have with them in the cockpit. I can imagine a conversation that must have been typical between pilots and instrument shop men about the time that direction-finders began to be common in airplanes. "Well—it's all right, but why should we have to sit up there and turn that crank around every time we want a bearing? Why can't you fix up something so we can just tune in the station and have the indicator point to the station?" Whereupon the instrument man, instead of telling him what you or I would have told him, went back to his shop, spent a week or two with his gadgets and emerged with the automatic direction finder—one that actually points toward any radio station to which its reeciver is tuned, and keeps pointing toward it as long as you like. You couldn't ask for much more than that.

When a young navigator who recently made his first trip across the Atlantic stepped out of the plane in Africa and was asked concerning his impressions of the trip, he delivered himself first of a huge sigh of relief and then of the brief but expressive comment: "Thank God for radio!"

During the early days of flying, pilots were also making demands for instruments to give them other types of information. For instance, after having been upside-down a couple of times when they thought they were right-side-up, and vice-versa, they began to ask for an instrument that would tell them which way was up. So they asked for, and got, the turn-and-bank indicator which aided them in maintaining an airplane in level flight and enabled them to be aware of, and to control, the turning and banking movements of the plane even though they might be in a dense fog, entirely out of sight of the ground, sky and everything else and even dizzy at the time.

They also got the directional gyro and the gyro horizon which further aided them in maintaining straight and level flight.

But, you know pilots. It wasn't enough that their instruments told them where and how to fly; it was only a matter of time until they reached the inevitable conclusion that the instruments should do the flying for them. "Why should we sit up there and wrestle with the so-and-so for hours and hours? Why can't you fix it up with some gyros and things so it flies itself?" So the instrument man did, and now we have the automatic pilot—a little box about so big, full of gadgets and things, which occupies the center of the instrument panel. The pilot now takes his ship off, straightens out on the appropriate heading, climbs to cruising altitude, turns the automatic pilot on and lets "George" do it, and then—well, what else would you expect?—he goes to sleep.

Probably we have not seen the end yet. Pilots, no doubt, even now, are conditioning themselves to the view that all takeoffs, climbs, maneuvers, descents, landings and even taxiing should be done by fully automatic instruments. And I have no doubt that as soon as they are confronted with the specifications, the instrument man will produce and deliver.

If a pilot were to walk into an instrument shop with a straight face and demand a space-compass, space-speed indicator and instantaneous three-dimensional position indicator for a contemplated space-ship trip to the moon, I should fully expect to see the instruments delivered within a month—complete with instructions for installation, use and maintenance.

While I may seem to have treated pilots and instrument men as in two distinct categories, I have not meant to imply that they are mutually exclusive or immiscible groups. There are pilots who are themselves instrument men—and good ones too—and vice-versa. One not infrequently meets old timers, both in the air and in the shops, who learned to fly in planes they built themselves and who helped to pioneer the development of some of the several dozen "clocks" that are now arrayed across their instrument panels.

Perhaps it is well that this versatility exists, for with the rapid automatization of all phases of flying there may be little need for pilots in the future. There will always be plenty of work for instrument men.

## Malin's Spring Steel Music Wire

(Useful information seldom available)

| No. | Diam. | Ft. per lb. | No. | Diam. | Ft. per lb. |
|---|---|---|---|---|---|
| 0000000 | .003 | 39000 | 24 | .055 | 124 |
| 000000 | .004 | 23433 | 25 | .059 | 108 |
| 00000 | .005 | 14997 | 26 | .063 | 94 |
| 0000 | .006 | 10415 | 27 | .067 | 83 |
| 000 | .007 | 7652 | 28 | .071 | 74 |
| 00 | .008 | 5858 | 29 | .075 | 68 |
| 0 | .009 | 4629 | 30 | .080 | 58 |
| 1 | .010 | 3749 | 31 | .083 | 54 |
| 2 | .011 | 2936 | 32 | .086 | 51 |
| 3 | .012 | 2604 | 33 | .091 | 46 |
| 4 | .013 | 2218 | 34 | .094 | 43 |
| 5 | .014 | 1913 | 35 | .098 | 39 |
| 6 | .016 | 1465 | 36 | .102 | 36 |
| 7 | .018 | 1157 | 37 | .106 | 34 |
| 8 | .020 | 937 | 38 | .110 | 32 |
| 9 | .022 | 775 | 39 | .114 | 29 |
| 10 | .024 | 651 | 40 | .118 | 27 |
| 11 | .026 | 560 | *Inch* | | |
| 12 | .029 | 447 | 1/8 | .125 | 24 |
| 13 | .031 | 391 | 9/64 | .140 | 20 |
| 14 | .033 | 344 | 5/32 | .156 | 16 |
| 15 | .035 | 305 | 11/64 | .172 | 12 |
| 16 | .037 | 274 | 3/16 | .187 | 10 |
| 17 | .039 | 247 | 13/64 | .203 | 9 |
| 18 | .041 | 223 | 7/32 | .218 | 8 |
| 19 | .043 | 203 | 15/64 | .234 | 6¾ |
| 20 | .045 | 185 | 1/4 | .250 | 5½ |
| 21 | .047 | 170 | 9/32 | .281 | 4¾ |
| 22 | .049 | 156 | 5/16 | .3125 | 4 |
| 23 | .051 | 144 | 3/8 | .375 | 2⅔ |

# Soldering Electrical Aircraft Instruments

By J. J. SCHILLER

**Instructor, Electrical Instruments, Pioneer Service School, Philadelphia, Pa.**

IN many instrument repair shops the soldering done on electrical aircraft instruments is a topic of frequent discussion. Unfortunately, the discussion usually settle down to a strictly pro and con basis with none of the participants being convinced of the others arguments.

In my opinion there is no argument. There is a right way and a wrong way to solder and it is up to us as mechanics in a chosen craft to do the job correctly. This is esepcially so considering the fact that some pilots life may depend upon the perfection of our handiwork.

Let us consider just what we are trying to achieve. In soldering electrical aircraft instruments we desire a tight clean joint, with no corrosive residue to harm delicate wiring and insulation. We desire a joint that will provide no cause for voltage leakage or increase in resistance due to oxidation of the contact points.

There is one and only one method of achieving this goal of a perfectly soldered joint and that is by the intelligent use of our soldering iron, by using a virgin metal solder of good quality and by using *rosin* as our fluxing agent.

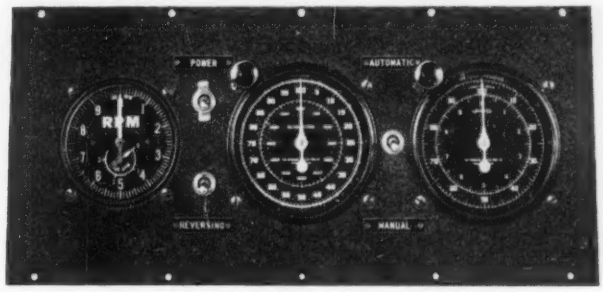
Let us go back to our statement that we desire a tight and clean electrical connection. Any connection that depends upon a strictly mechanical bond is sure to work loose in time. The constant vibration of the mechanism or the contraction and expansion of the metals due to temperature changes will surely work loose any mechanical contact. This is both dangerous and annoying in the case of electrical connections—dangerous because of mechanism failure and fire hazard and annoying because of the time involved and trouble encountered in finding loose connections and restoration of continuity. Then too, oxidation of the contacting parts presents a serious hazard to good electrical contact. No matter how tight we secure our terminals, oxygen will penetrate and oxidize the surfaces, setting up a resistance that is detrimental to accurate operation.

How then are we to surmount these difficulties? Let us

THE STANDARD ELECTRIC TIME CO.

*Announces a*

NEW CHRONOTACHOMETER

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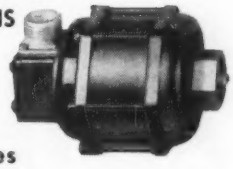

AN ELECTRIC DRIVE is the improved feature of this instrument: —

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A 3-CONDUCTOR CABLE is furnished between the generator and two 3-PHASE RECEIVING MOTORS in the chronotachometer running in synchronism with the generator.

ONE RECEIVING MOTOR drives the tachometer unit.

ONE RECEIVING MOTOR drives the revolution counter unit.

BOTH TIMER AND REVOLUTION COUNTER are our standard clutch-controlled movements and operate by the same control circuit.

NO FLEXIBLE SHAFT is required.

THE TACHOMETER has a SCALE-LENGTH of 30.25" full scale and is a flight instrument manufactured by General Electric Co. (their No. DJ-13). Location of tachometer, revolution counter and timer movements is not restricted and since there is no mechanical connection between them, any one of the three may be mounted on a panel remote from the others.

**ACCURACY IS:**

TIMER to within .001 minutes per test run.
REVOLUTION COUNTER to within ½ revolution per test run.
TACHOMETER to within 10 RPM throughout the scale range.
Thus extreme accuracy of speed measurement may be obtained by prolonged integration of time and revolutions.

AUTOMATIC 1/10th minute integration (RAPID SPEED CHECK) is included on this and all other types of chronotachometers.

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LEADERSHIP THROUGH APPLIED RESEARCH

suggest a few good rules that we have found from experience and from the recommendations of solder and flux manufacturers.

*1. Make a Good Mechanical Connection First, Then Solder Bond!*

There are occasions where a mechanical connection is not feasible or practical. Under these circumstances, well cleaned contact points, correctly tinned, will solder with a lasting bond that proves satisfactory. However, in most cases a firm mechanical bond is possible and solder will seal the joint against the dangers of oxidation and loose connections.

*2. Use Only Rosin Flux.*

Flux is a subject that causes most discussion and much can be said concerning the merits and qualities of acid core, "non-corrosive" pastes and waxes, both good and bad. We will adhere most strictly to our claim that only Rosin is to be used in electrical instrument soldering and we defend our position with some well established facts and examples.

Solder fluxes can be divided into two general categories: (a) corrosive; (b) non-corrosive.

In the first category belong all acid fluxes, dilute chloride of zinc, sal ammoniac, solution of magnesium, calcium and certain other metals.

In the second category belongs only Rosin, despite various claims of flux manufacturers to the contrary.

The purpose of a flux is to dissolve any oxide that covers the surfaces to be soldered so that the molten solder can unite itself with the metal surface and prevent any further oxidation.

Acid fluxes eat away the oxidation, it is true, but they eat away the metal contacts and the soldering tip and have a harmful after-effect on insulation.

Acid fluxes have a great affinity for moisture, and long after the soldering job is completed the delicate wiring and insulation will rot and corrode away and dielectric losses will occur over all the area adjacent to the soldering joint.

Some fluxes are composed of weak acids in a grease or wax medium, with the idea that the grease or wax will prevent corrosive action. This too is a fallacy that should be well realized. The corrosive action is strictly chemical and no amount of grease will cover it up. The grease only accumulates dust and grit and upon the application of a hot iron will spread through insulation and cause a gradual rotting away of its important protection.

Consider the fate of a delicate instrument bearing or rocking shaft pivot that has become accidently smeared with an acid flux from an untidy workbench! Or the finely insulated wiring of a voltmeter-type tachometer that has been supposedly scrubbed of its acid fluxing agent by a solvent that merely spread the havoc over a greater area!

Having made various experiments by smearing so-called "non-corrosive" fluxes over polished specimens of steel and copper, we found that after a period of a few weeks *only the rosin flux specimen* was not discolored or corroded.

Granted that acid fluxes do a faster job of cleaning the work and are easier to use, but would we rather do a good, clean, safe job of soldering *now* with fewer complaints and less trouble-shooting *later?* I think we would.

*3. Use a Good Grade of Solder.*

Solders can be of various percentage compositions and have different characteristics. We shall be concerned with only those solders that are acceptable for our specific purpose.

Solder is composed of tin and lead in various percentages.

A high tin content makes a solder brittle and crystalline. You can check your solder by bending it sharply and noting the surface at the bend. If fine cracks develop, they are an indication of a high tin content. If the solder bends easily, is ductile and has low tensile strength, it has a high lead content.

The solders most commonly used for our work contain a mixture of 40-60, 45-55, 50-50 and 60-40, the first percentage figure indidcating the tin content.

A solder containing 63% tin and 37% lead will have no plastic stage between solid and liquid. In other words, as soon as the temperature reaches 358°F., the solder will immediately change from solid to liquid form. When we change either of the percentages we will then experience a plastic or mushy stage in the transfer from the solid to the liquid state. This is a positive means of indicating that our soldering iron is not delivering enough heat to the work.

It is important that the solder used is manufactured by a reputable firm, and is of virgin metals. Otherwise, we shall have all kinds of trouble with impurities in the metal, various melting points and gradual disintegration of the soldered joint.

*4. Tin the Work First—Then Solder.*

The metals to be soldered should be bright and clean, free from dirt, grease or any plating.

Naturally, any insulation should be skinned off, with care not to cut into the wires beneath and the wires should be gently scraped of any lacquer or varnish. Stranded wires should be first twisted into a tight, single wire and long, loose strands should be cut off evenly.

The soldering copper should then be applied to the work with the purpose of bringing the wiring to a temperature sufficient to melt the solder, and only then is the solder applied to the *work*, not the iron.

In using rosin core solder, frequently we find that the solder has no rosin flux in the first quarter inch or so. This flux has flowed out at a previous application. It is therefore necessary to melt away this slight amount of solder before fresh rosin will flow. Do not, however, try to use these solder drippings with another flux. Always use fresh solder and fresh rosin. Solder drippings can be gathered and sold for just what it is—junk.

Rosin disintegrates with heat and its action becomes sluggish when exposed to the atmosphere for some time. Hence, our admonition—use fresh rosin and insure a clean joint. A clean, correctly tinned joint has 99% of the soldering job done.

*5. Use the Soldering Iron Intelligently!*

The soldering iron best suited to our purpose is the electrically heated jewelers' iron or small 30-watt commercial iron. These are tools of fine design and purpose and should be treated as such. They provide a means of easily controlled, continuous flow, economical heat conductivity that is ideal.

The electric iron should be connected to the proper voltage and as the heat rises is tinned on all four surfaces. This tinning is applied by touching the hot tip with rosin core solder and permitting the rosin to flow over its surface. AN IRON THAT IS TOO HOT WILL BLACKEN THE COPPER AND BURN THE ROSIN.

A burned copper will never tin satisfactorily, consequently will never solder satisfactorily. The black, dirty crust of oxidation will insulate the soldering copper from the work, will prevent adequate transfer of heat and will foul up the solder. Keep your eye on the tinning as a sure indication of the proper temperature for the iron. By disconnecting the plug for a few minutes we can save ourselves from a messy job and lots of grief.

Never use sal ammoniac to clean or tin iron in electrical work. Its after-effect is always in conspicuous evidence.

During the soldering operation an occasional rubbing of the tip over a piece of steel wool will restore the original luster to the tinning and keep the tip clean.

It will be noted that an iron in continuous operation will become pitted. This is a sign that the tool is performing its job efficiently as a soldering implement. A metal, to be a good soldering tip, must partly dissolve in molten solder so that it can continually form and reform its solder coating or tinning.

Copper is a metal of high heat conductivity and oxidizes easily, and therefore it is a good material for our soldering tip. It is soft, however, and wears away from continual use. Therefore, when the point has become dull and pitted a new soldering surface must be reformed by filing it into a


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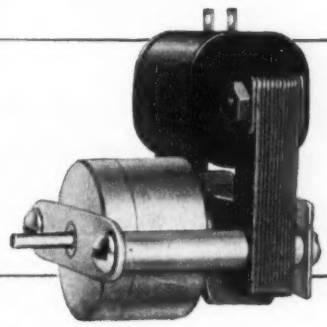

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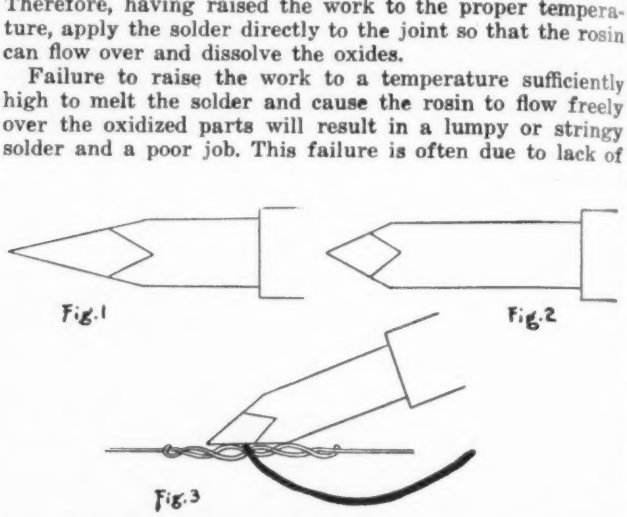
clean, even point. After this operation it must be completely retinned as directed above.

Once the tip has been tinned, we are no longer interested in applying more solder to our iron. The soldering operation will automatically keep the iron tinned. What we are primarily interested in is applying solder to the work. Therefore, having raised the work to the proper temperature, apply the solder directly to the joint so that the rosin can flow over and dissolve the oxides.

Failure to raise the work to a temperature sufficiently high to melt the solder and cause the rosin to flow freely over the oxidized parts will result in a lumpy or stringy solder and a poor job. This failure is often due to lack of




heat conducting surface of the iron or failure to apply this heated surface correctly. Figs. 1 and 2 illustrate a correctly and incorrectly shaped tip and Fig. 3 illustrates the proper application to the work. A long tapered point presents too much heat radiation surface to the atmosphere and too little to the work. Remember—a correctly tinned iron, correctly applied gives a neat, workmanlike joint.

*6. Take Care of Your Iron.*

A good iron is a good tool—take care of it. When not in use keep the cord wrapped neatly around the handle. Keep it from overheating and keep it clean, and your iron will keep you out of soldering trouble.

---

## A "Quiet Buzzer" (Vibrator)


**By RAY J. STEPHAN**
**Administrator, Pioneer Instrument Service School, Philadelphia, Pa.**


IN the overhaul and calibration of aircraft instruments one of the essential requirements in test equipment is a source of controlled vibration, to eliminate static friction in the instrument mechanism under test. The object is to reproduce conditions encountered in the actual use of the instruments in aircraft operation—in flight or on ground run-ups, a certain amount of vibration is always present.

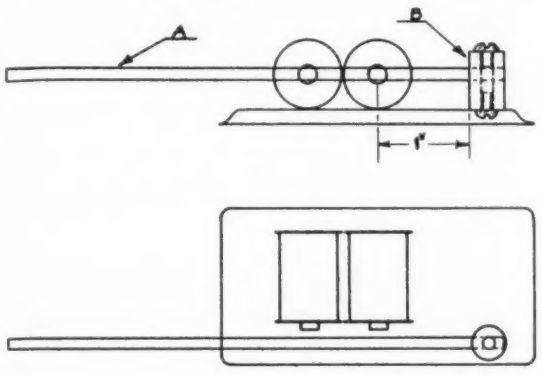
Unfortunately, the *easiest* way to develop vibration is to go to the five-and-ten or to a hardware store (before material shortages) and purchase a door bell or buzzer. A small door-bell transformer supplied the needed electrical energy, and away we go. *But*, besides vibration you also acquired a lovely noise-producing machine. To listen all day to buzzers a-buzzing away is enough to drive you batty, particularly when a buzzer is developing its usual pitted points and the noise level varies from high to low and the audio-frequencies from screechy to raspy to burry to roary and back again to shrieky. Really it becomes terrific (or am I telling you?).

Well, here is my answer to the challenge of "buzzer nerves":

This particular buzzer that was worked over started out in life as a door bell. The entire moving element (armature), including points and bell weight, was removed and gently deposited in the local metal scrap collection along with the bell itself. The solenoid coils were rewired so that the flipping of the on-off switch supplied energy directly to the coils. (On the original setup the electrical energy passed

through the make-and-break points operated by the armature.)

The d-c. resistance of the solenoid coils in series was 5 ohms on this particular unit. Each coil was approximately $1\frac{1}{16}$" diameter $1\frac{5}{16}$" long. The coils were energized by a 10-volt 60-cycle supply obtained from a step-down transformer. Now, referring to the simple sketches: *A* is a piece of 0.110" diameter drill rod or cold-rolled steel. The rod is $5\frac{3}{8}$" long, which for this particular pair of coils develops plenty of resonance and consequently plenty of vibration. The rod just sits there and vibrates like hell and not a sound out of it. Really quite wonderful. *B* is a piece of $\frac{3}{8}$" diameter brass rod. A #37 drill is used to drill the hole




through the brass rod, the long way. The ends of the hole are tapped 6-32 to take the mounting screw and the set screw for the holding of the rod. A #35 drill will give a hole of sufficient size to clear the 0.110" diameter rod. The distance from the edge of the point of support of the rod to the center line of the closest solenoid coil is 1". By varying the length or the rod, one may readily vary the intensity of the vibration.

No doubt other improvements could be made on this device, perhaps we should patent it, but let me restate, it is a "quiet buzzer" and that in itself is sufficient for this humble follower of the aircraft instrument field.

## Magnetism and Electricity as Utilized in Aircraft Instruments

By RAY J. STEPHAN

Administrator, Pioneer Instrument Service School, Philadelphia, Pa.

WITH the coming of large multi-engined aircraft it has become increasingly difficult to depend on purely mechanical instruments for transferring to the instrument panel essential information on the operating condition of the power plants. The distance has become too great. Electrical coupling has come along to aid this situation.

In other instances it has been found that electrical instruments are more accurate and easier to service than equivalent mechanical instruments.

The electrical coupling of the magnetic compass for remote indication has also come along to help solve a sometimes serious problem: local magnetic effects in the cockpit often make it difficult to compensate a compass located in the cockpit but with an electrically-coupled compass the master unit may be located remotely in the aircraft, away from the magnetic disturbances.

An outstanding advantage of electrical instruments in large ships is the ease with which repeater units may be employed at several points. For example a compass indication is useful to the pilot and to the navigator and often to the radio operator. An electrically coupled compass satisfies this requirement.

Unfortunately, in our study and work on electrically or magnetically operated instruments, we cannot see the elec-

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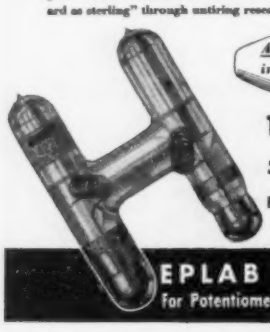

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trical and magnetic "forces" or the "fields" or the "lines" of force. In a modern aircraft instrument school, therefore, an effort is made to do the next best thing by explaining the effects of electrical and magnetic phenomena as simply as possible, to clear up the air of mystery surrounding electrical and magnetic aircraft instruments. This article summarizes classroom talks by the writer.

### MAGNETISM AND MAGNETS

Many electrical instruments employ magnets. The magnetic compass, the electric tachometer, the gyro element in the gyro-stabilized driftmeter, the Autosyn flowmeter transmitter—all use a magnet in their operation.

A magnet may be in the form of a bar, disk or horseshoe. The molecules of the magnet material (or some of them) are lined up or "oriented" in an orderly way, so that the magnet as a whole possesses polarity: it has pairs of poles. Most magnets used in aircraft instruments have either two or four poles—always paired up: 1 North pole and 1 South pole or 2 N and 2 S. Between the poles of a magnet, the magnetic lines of force are invisible, but their *effects* are capable of being detected and measured. These lines of force or magnetic fields have dependable laws governing their action.

One of these dependable laws is the attraction between unlike poles and the mutual repulsion of like poles. Another dependable characteristic is that a bar magnet, free to rotate, will align itself parallel to the lines of force of any other magnetic field in which it may be placed. Common example: the compass needle in the earth's field. These and other characteristics never fail!

Magnets are used on Bendix Pioneer instruments for the following purposes:

(1) As a coupling to transmit torque from one shaft to another. The Flowmeter Autosyn transmitter is an example.

(2) As a device to generate eddy currents in a nonferrous disk or cup, commonly called a magnetic drag system. This application is found in the gyro unit of the B3 driftmeter and also in the electric tachometer.

(3) Magnets are the prime mover in a magnetic compass, and also in the Magnesyn.

(4) The field of a four-pole magnet is used to generate an electric current in the engine unit of the electric tachometer.

(5) Magnets are used to effect compensation of the magnetic compass and Magnesyn.

It might be well to mention at this point that the magnetic pole of the earth in the region of the geographic north pole is the same as the south pole of a magnet: it attracts the north pole of a permanent magnet. The end of a compass needle which points north is its *north-seeking* pole. Custom drops the word "seeking."

### CURRENT FLOW—VOLTS, AMPS AND OHMS

*Electromotive force* (emf.) is the electric "pressure" which makes an electric current flow in an electric circuit. The *Volt* is the unit of emf.—named after Volta who built the first wet battery. One volt is required to force a unit of electric current against a unit of electrical resistance in a d-c. circuit.

*Current* is the rate of flow of electric energy. The unit of current measurement is the *Ampere*, named for the French scientist who discovered electromagnetism. The value of the current which flows in a conductor is dependent on the voltage and on the resistance.

The *resistance* of an electric circuit is measured in ohms. This unit is named for Georg Simon Ohm who formulated the law we shall take up presently. The resistance of an electric circuit element, such as a conductor, depends on: (1) the material of the conductor, (2) the length of the conductor, (3) its cross-sectional area and (4) its temperature.

### OHM'S LAW

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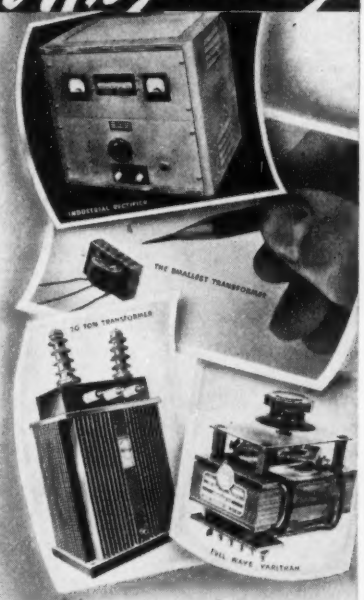

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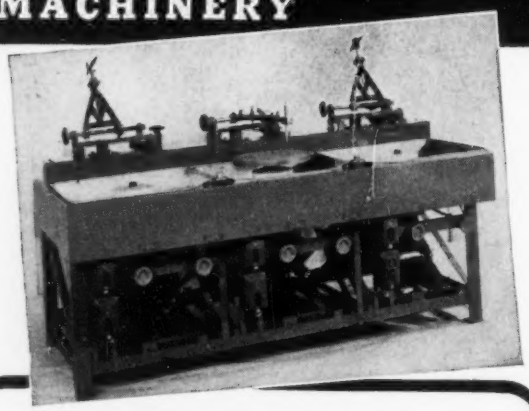

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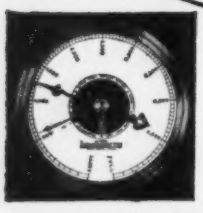

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ergy that flows in a circuit is greater with an increase in the impressed voltage and less with an increase in the electric resistance. Expressed as a formula, remember the word "IRE." $IR = E$. $I$ = Current, $R$ = resistance, $E$ = emf. or voltage. Ohm's Law in this form applies to direct currents only.

### CURRENT FLOW IN A CONDUCTOR

Whenever a current flows in an electric conductor (imagine a *straight* wire at first), a peculiar thing takes place: At right angles to the flow of current, a magnetic field builds up. This magnetic field takes the form of a series of concentric circular patterns extending all around and all along the conductor. This magnetic field is capable of exerting force and doing work. No one has ever actually observed a magnetic field, but there are many ways of detecting its presence. If you approach a current-carrying conductor with a magnetic compass, the compass needle will be deflected. If you take a length of wire and make a coil of it and connect the ends of the coil to a source of electric energy, an electromagnet will be the result. The strength of such an electromagnet may be considerable. In this coil you have concentrated the magnetic lines of force. If you wrap the coil around a piece of soft iron you will still further increase the effectiveness of the electromagnet.

This innocent and relatively simple proposition of a magnetic field built up around a current-carrying conductor gives us many of the advantages of electricity as applied to aircraft instruments. If you have a good clear picture of this proposition in its several aspects you will have little trouble understanding the operation of most electrical instruments.

Getting down to details in our consideration of current flowing in a conductor, the first point to consider is the direction of motion of these concentric magnetic lines of force encircling a conductor. The *Right-hand Rule* covers this problem very neatly. If we grasp the conductor in the right hand, with the thumb pointing in the direction of current flow, the fingers are then encircling the conductor in the direction of "flow" of the magnetic lines of force.

The right-hand rule may be applied in a slightly different way to solenoid or electromagnet. Grasp the coil in the right hand, the fingers encircling the coil in the direction of the current flow. The extended thumb points to the north pole of the solenoid.

Remember that the magnetic field of a current-carrying conductor is every bit as much of a genuine magnetic field as that found associated with a permanent magnet. Also remember that the plane of the magnetic field set up by a current flowing in a conductor is always at *right angles* to the direction of current flow.

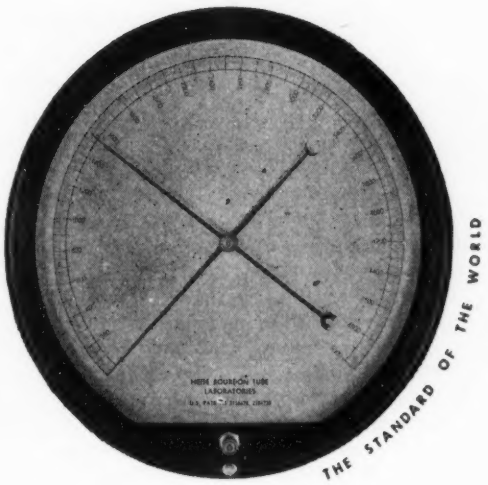
### DIRECT AND ALTERNATING CURRENTS

A direct current is that type of current which flows in one direction. As a consequence the direction of the magnetic lines of force surrounding the conductor also remains the same. In a solenoid energized by d.c., the polarity of the solenoid remains the same for a given direction of current flow through the coil.

An alternating current is one whose direction of flow reverses at regular intervals. In discussing alternating current it is customary to express the voltage and the cycle value. The usual house current, for example, is a 110-volt 60-cycle current, which reverses its direction 120 times per second (one cycle being equal to two complete reversals). The miniature Autosyn is supplied with 26-volt 400-cycle current.

A solenoid with a.c. flowing in it would have its polarity reversed every time the direction of current flow was reversed. If the frequency of reversal was fast enough, say 60 cycles or over, a magnetized needle would point steadily toward one pole of the solenoid. The only trouble would be that the magnetized needle would point toward *either* end of the solenoid according to which end was closest to the end of the needle initially.

A great many more things can be accomplished with a.c. than with d.c. A.c. is utilized in practically all Bendix

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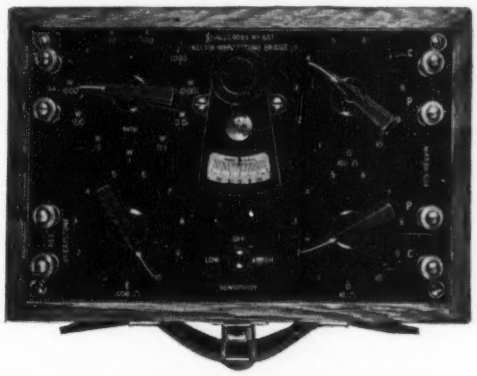

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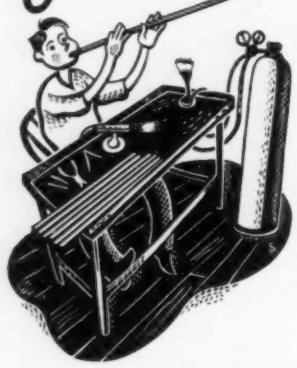

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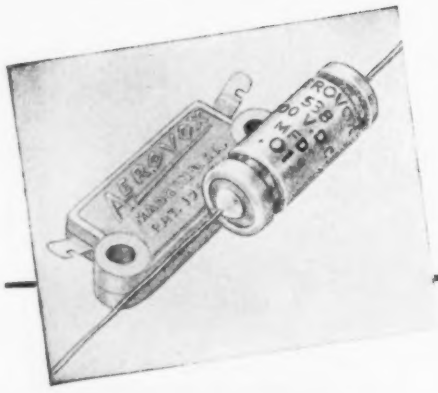

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Pioneer electrical instruments. Consequently we will spend much of our time discussing a.c., its uses and effects.

### THE TRANSFORMER

One of the most important advantages possessed by a.c. is its ability to transfer electricity from one electric circuit to another without the use of any direct electrical connections and—by extremely simple means—to "transform" the voltage of the first circuit to a higher or lower value in the second circuit. This process of transferring electrical energy through space is called induction. Current from one conductor is induced in another conductor. The induced current in the "secondary" will have the same frequency as that of the current in the "primary," whereas the secondary voltage will be higher or lower than the primary voltage.

This induction or transferring process depends on *the basic electromagnetic phenomenon* which is that *a changing magnetic field creates an electromotive force.* If we take a coil of wire and pass a bar magnet through the center of the coil—thereby *varying* the magnetic field to which we expose the coil—a momentary current will flow through the coil of wire. This takes place because whenever electrical conductors are "cut" by magnetic lines of force, an electromotive force is created and therefore an electric current will flow in the conductors involved, provided that the conductors are part of a closed circuit.

The really important thing to note here is that the current flow is set up only when the magnet is moved in or out of the coil, or when the coil is moved along the magnet—it doesn't matter which moves: the essential is the variation, or change, so that lines of force cut a conductor or so that a conductor cuts lines of force.

Now, in the case of a direct current flowing in a conductor, the magnetic swirls which exist around the conductor build up when the current is turned on and stay built up until the current is turned off. Therefore, if we place a coil near this conductor of d.c., no current will be induced in the coil while the d.c. flows continuously and evenly (without changes of direction or of voltage).

Things are different in the case of a conductor of an alternating current: The magnetic swirls build up, then die down and build up in the opposite direction. This build up, dying down and reversal (in *time*) has the same effect as the moving of the bar magnet in and out of the coil of wire (in *space*). These magnetic swirls "moving" in one direction then in the other direction are capable of "cutting" any conductor placed in their immediate vicinity. Thus they induce a current or transfer a current from one circuit to another.

If the number of turns in an a.c.-energized coil is exactly 100 and the number of turns in a nearby coil is also 100; and if the two coils are built into an arrangement that prevents leakage of electric energy, then the value of the voltage and current in each coil will be the same. (The frequency, of course, will also be the same, as explained before.)

If, however, we have 200 turns in the second coil, then the voltage in the second coil will be twice the voltage in the first coil. Then we can say literally we have a "transformer." Our device "transforms" voltage from one value to another value. In every-day life, however, even in an instance where no step-up or step-down in the "secondary" voltage occurs, we still refer to the device as a transformer.

The transformer winding connected to the current supply is known as the primary; the winding connected to the receiver circuit is known as the secondary.

The Autosyn remote system of indication consists in part of two self-synchronizing motors. These motors are really a form of a special transformer—the "star" winding type of transformer.

The Magnesyn remote indicating compass operates as a special form of transformer having a winding known as an "open delta."

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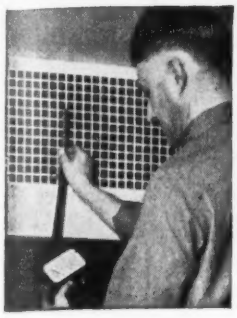

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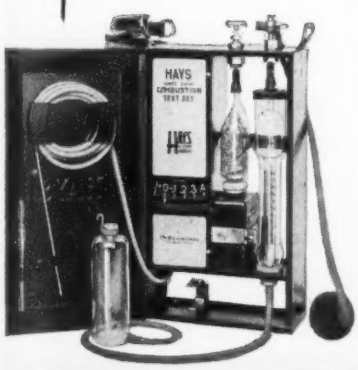


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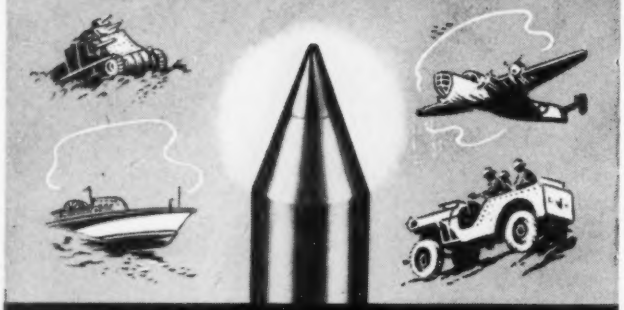

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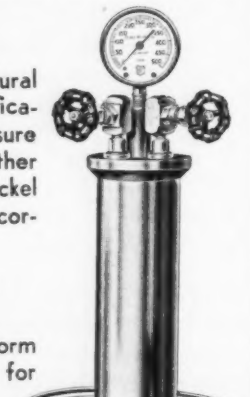

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permeable is meant that the iron readily absorbs magnetic fields and just as readily gives them up again. The iron (or iron alloy) is formed of very thin strips of metal rather than in one solid piece. These laminations, as they are called, are also painted with the equivalent of a clear lacquer. The use of laminations and the painting go together to cut down the development of so-called "eddy currents" which set up a heating effect (representing a loss in electrical energy) and which are otherwise undesirable.

### EDDY CURRENTS

Eddy currents are electric currents which are induced in any piece of metal moving across a magnetic field. The strength of the eddy current is dependent on the mass of the metal involved. For this reason, the laminations and insulation mentioned above are employed where eddy currents are undesirable. This makes the individual mass small.

Eddy currents may be developed in a piece of metal even though that metal does not form a "closed circuit." To acquire a mental picture of this phenomenon, consider a ring-shaped portion of the metal. Think of it as a shell. This imaginary shell, separated by your imagination from the rest of the metal, is a closed conductor as we are accustomed to thinking of such things.

The motion of this "shell" across a magnetic field sets up a flow of current in a real circle—a ring within the metal—this circular current being far from imaginary. Due to the low electrical resistance of a large piece of solid metal, the value of the induced current can easily be very great. The large current flow produces a heating effect. The direction or current flow is such as to oppose the original motion of the mass of metal (for a reason that will be explained presently). This opposition is undesirable in many cases as it consumes energy needed for other work. In those cases we do not want eddy currents because they are not useful. But sometimes we set up mechanical devices deliberately to develop eddy currents because we find them useful.

A Frenchman, Dominique François Arago, found that by rotating a magnet on a shaft and placing a non-ferrous disk near the rotating magnet, the disk could be set to rotating also. The direction of rotation of the disk was the same as the direction of rotation of the magnet.

The "mysterious" connecting link between magnet and disk is our friend Eddy Current. The induced eddy currents being ring-shaped, they have at least one property of a solenoid: they have a magnetic field of their own. Now, then, the interaction of *these* magnetic lines of force with the magnetic lines of force of the rotating magnet gives us the needed connecting medium to produce rotation of the disk. The rate of rotation of the disk is always lower than the rate of rotation of the magnet. If this were not the case, no "induction" would take place in the disk. Remember: actual cutting of lines of force is needed to induce a current in a conductor. This difference in rate of rotation gives the continuous "cutting" action.

The rotating-magnet-and-disk arrangement is utilized to good advantage in the Pioneer electric tachometer, in the gyro erecting device on the driftmeter and Fluxgate and, last but not least, in the speedometer of your car.

### RESISTANCE IN SERIES AND PARALLEL

It may be necessary, as a check on the condition of certain electrical aircraft instruments, to test the d-c. resistance of parts of the unit. Some of these component parts may be connected in series and others in parallel.

Here are a few simple rules governing series and parallel hookups.

In a *series circuit* the current flows through the various resistances in succession. The total resistance of a number of resistances in series is the sum of the individual resistances. The current is the same throughout a series circuit. However, the more conductors in series, the greater the resistance, and hence the smaller current.

In a *parallel circuit*, the current divides and flows simultaneously through the various resistances. The total current

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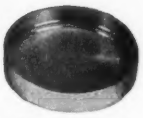

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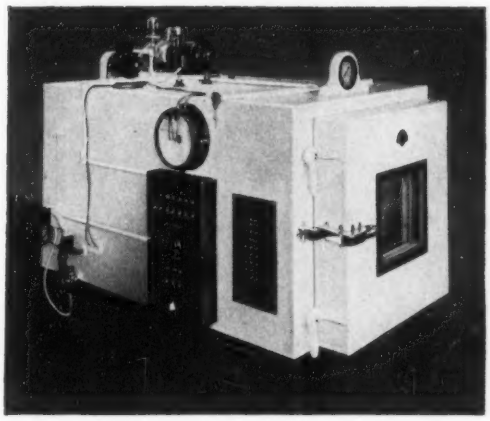

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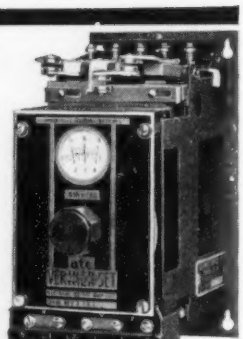

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is the sum of the current in all the branches. The voltage is the same across each of the resistances in parallel. The total resistance of a parallel circuit is less than that of any single resistance in the circuit.

End of Guest Editor's section of *Aviation Instruments*

# AIRCRAFT INSTRUMENT GUILD

INTERNATIONAL HEADQUARTERS

812 N. DELAWARE PLACE
TULSA, OKLAHOMA

*The following articles have been contributed by the Aircraft Instrument Guild. For further information on any of the subjects discussed, write to the Guild at the above address.*

## The Shoe Will Fit Us Also

By R. G. OJERS
President A.I.G.
Spartan School of Aeronautics, Tulsa, Okla.

IN the last issue of this magazine, we had an article on "Standardization Through Coöperation" of the manufacturers, referring to instruments, and after reading this article over, I see how it could so easily be applied to us instrument mechanics.

"Standardization Through Coöperation." Each of us as an individual working in small groups has learned certain routines and procedures in doing a job well, but one method will be different from another, some much better than others. As you know, it is the purpose and aim of the Aircraft Instrument Guild members to exchange ideas. We should all coöperate with one another that we may choose the best methods, thereby becoming better mechanics both for ourselves as well as our employers, not only on the overhauling of instruments but line work, trouble-shooting and installation. Tools or jigs designed especially for aircraft instruments constitute another helpful subject that is definitely beneficial to us all.

Now for our *own* benefit, let's look around at our work—how we do it. Have we some original method, or methods, given us by our neighbors? Or some factory representative? They may appear obvious and of little or no consequence. Swell! Just sit back and say to yourself, "Well, it has helped me—why shouldn't it help someone else?" Write it down, draw a sketch, then send it to us for publication that everyone may benefit. Can't you just visualize the knowledge to be gained by all instrument mechanics if each of us should send just one idea? Talk to your fellow mechanics—encourage them to join. Let's bring our organization of the Aircraft Instrument Guild to the front, not just through publicity alone, but through activity and progressive accomplishments.

Mr. O. E. Patton, of the C.A.A., who is an Honorary Member, has made known to us his intentions of coming to Tulsa in the next few weeks with the view in mind of giving us information on furthering our aims of being certified mechanics. So any of you that are interested in having the skill of your trade recognized by the Civil Aeronautics Administration, let's get together and show we mean business.

## Guild Announcements

Fred Neff has been appointed Treasurer of the Aircraft Instrument Guild, replacing Mr. Lyle Harvat.

Fred E. Honeycutt has been appointed Recorder, replacing Everett M. Allsman who is now employed with the Stanolind Oil Company, not actively engaged in aircraft

instruments, and hence relieved from active work as a Guild member.

The appointment for Vice-President has not been made to date, in filling the place vacated by Richard L. Davis who, with Lyle Harvat, is now with the Lockheed Overseas Corporation; both of them going into foreign service as civilian instrument technicians.

We who must remain behind take this opportunity to publicly thank them all for their coöperation.

Mr. Neff and Mr. Honeycutt are both charter members and their willingness to serve as officers is greatly appreciated.

But we still need a lot of help from the rest of the members. —R.G.O.

## Chapter No. 2 Organized in Omaha, Neb.

On July 17, 1943, at 7:30 p.m., at the Omaha Aircraft Company, Omaha, Nebraska, a meeting was held for the purpose of organizing Chapter Two of the Aircraft Instrument Guild. Acting as temporary chairman, Mr. A. F. Cone opened the meeting by reading a letter from President Ojers of the Guild, dated July 9. The By-Laws were read. A motion was made that at least two candidates be nominated for each office and that a vote be taken on the candidates nominated for President before nominations for Vice-President be in order so as to allow a defeated candidate to be eligible for some of the offices. The motion was seconded and carried.

The results of the election were as follows: *President*, A. F. Cone; *Vice-President*, G. Jelen; *Secretary & Recorder*, W. Mather; *Treasurer*, K. Olson.

President Cone appointed the following committees: *Publicity:* V. Ortman, Chairman; M. Baker; L. GeBauer. *Social & Membership:* T. Barker, Chairman; M. Baker; D. Wilson; R. Hersch; O. Burgess. *Educational Committee:* L. GeBauer, Chairman; K. Olson; E. Lewis; H. Klug; T. Dowd; G. Fought.

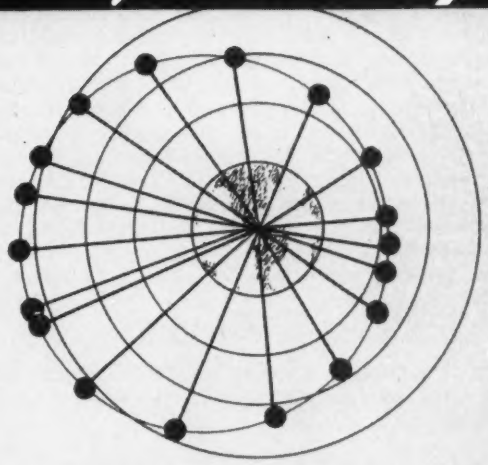
A motion was made that the Chapter meet again Saturday, July 31 at 7:30 p.m. at the same location and regularly on *the second Saturday of each month thereafter.* The motion also stated that we should have dinner together before the meeting but it should not be compulsory. Motion carried. A motion to appoint a committee to prepare a Constitution and By-Laws for presentation at the next meeting. Carried. *Committee:* A. J. Cone, G. Jelen and W. B. Mather.

## Sources of Error in Precise Commercial Refractometry

CERTAIN modifications of the Abbé type refractometer, which have extended its field of application to precise measurements, make it advisable to examine possible sources of error in order that greater accuracy may accompany increases in precision. In the April *Bureau of Standards Journal of Research* (Research Paper No. 1535) Leroy W. Tilton points out that the quality of optical surfaces on lenses and prisms must be high because, in general, the symmetrical use of all apertures is not possible. Approximate corrections for different performance of the instrument at different temperatures are not adequate at water-jacket temperatures differing widely from those of the room, but it is seldom necessary to distinguish between index of sample referred to air at water-jacket temperature or to air at room temperature. When using solid samples the prismatic effect of contact liquid must be carefully eliminated; only one-third interference fringe per centimeter along the contact surface is permissible, as viewed in the exit pupil of the telescope.

For refractometry of liquids certain compromises seem necessary. The illuminating prism should be set close to the refracting prism in order to retain the sample and admit light at truly grazing incidence. On the other hand, the separation should be somewhat larger to eliminate troublesome interference fringes which can cause masking of the critically refracted rays. The surface of the illuminating prism should be polished or fine ground to facilitate cleanings and to allow maximum transmission when working with spectral sources of low intensity. On the other hand, a rough-ground surface eliminates the interference fringes that cause masking.


*in 127-151 Ptolemy*



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## Forced-oscillation Approach to the Problem of the Controlled Continuous Process

*Concluded from Page 476*

It is evident then that any sine wave disturbance will pass through the process with less distortion than those of other shapes. As we have seen, the ideal control mechanism resembles a simple oscillating system and would produce a simple harmonic "output." This "output" would then introduce a sine wave action into the valve which would pass on down the process to be measured and be reintroduced into the "input" of the controller. An automatic-control circuit is a round-the-circle or dog-chasing-his-tail proposition. Since we have had the problem of closing the circle by connecting the action of the valve to the measuring element, it is fortunate that the action on the process will be a sine wave since this or the cosine is the only function which will easily express a wave traveling along a process.[2] We may say then that when

$$Q_s = Q_{s\max} \sin Kt, \; T_w = cQ_{s\max} \sin(Kt - \phi),$$

or the temperature wave is a definite percentage of the steam wave but differs in phase by an angle $\phi$ as shown in Fig. 9.

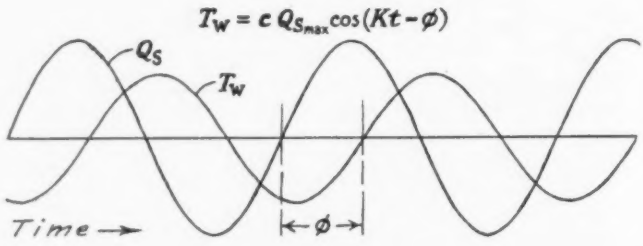


Fig. 9. Process lag.

The control circle is now completed and the next thing to do is see if the whole thing might not perform as a forced oscillating system. First consider the equation[3] for a simple mechanical oscillating system shown in Fig. 7.

$$S = F\theta + D\frac{d\theta}{dt} + M\frac{d^2\theta}{dt^2}$$

where $S$ = applied force, $D$ = damping coefficient, $\theta$ = displacement, $M$ = mass or inertia, $F$ = restoring force coefficient

If $S = 0$, or no external force is being applied to the system, it will follow one of the transient curves below depending on the relationship between the three constants:

$\theta = e^{-Dt/M}\,(m_1 e^{Kt} + m_2 e^{-Kt})$ when $D^2/F > 4M$;
$\theta = e^{-Dt/M}\,(at + b)$ when $D^2/F = 4M$;
$\theta = e^{-Dt/M}\,(m_1 \sin lt + m_2 \cos lt)$ when $D^2/F < 4M$;

where the above constants depend on $F$, $D$, $M$.

If $S = E_{max} \cos pt$, or a simple harmonic force is applied to the system, it will follow the curve below:

$$\theta = e^{-Dt/M}\,(m_1 \sin lt + m_2 \cos lt) + K_3 \cos(pt - \phi) \quad \text{when } D^2/F < 4M$$

where the constants depend on $D$, $F$, $M$, $E_{max}$, $P$. It is evident that the difference in the above systems for the forced and nonforced conditions is the term $K_3 \cos(pt - \theta)$. This means that each system will come to rest after a disturbance depending on the values of the constants except that the forced oscillating system will continue to vibrate at the frequency of the forcing oscillation, but out of phase.

(2) C. O. Fairchild. "Elementary Theory of Automatic Temperature Control." *Instruments*, Vol. 13, Nov. 1940, pages 334-339.

(3) John H. Neely & J. I. Tracy. *Differential and Integral Calculus*. Macmillan Co., New York. Page 474 of first (1935) edition; page 476 and second (1939) edition.

Returning to the process again let us start with the steam flow.

$$Q_s = K_s V,$$

$$\text{or } \frac{dQ_s}{dt} = K_s\frac{dV}{dt} = K_s\,(A\Delta + B\frac{d\Delta}{dt} + C\frac{d^2\Delta}{dt^2})$$

Then, when $Q_s = Q_{s\max} \sin Kt$

$$\frac{dQ_s}{dt} = \frac{d(\sin AY)}{dt} = A\cos Y$$

$$= Q_{s\max} \cos Kt = K_s\,(A\Delta + B\frac{d\Delta}{dt} + C\frac{d^2\Delta}{dt^2})$$

$$= P\Delta + J\frac{d\Delta}{dt} + R\frac{d^2\Delta}{dt^2}$$

the solution of which is, as for the mechanical system

$$\Delta = e^{-Jt/R}\,(m_3 \sin lt + m_4 \cos lt) + K_4 \cos(Kt - \phi)$$

where $K_4$ and $\phi$ are dependent on the constants $P$, $J$, $R$ and $KQ_{s\max}$. It is evident that if $\phi$ is of such value that it coincides with the phase difference produced by the process lag, conditions for sustained oscillations are set up. If the constants are changed to throw $\phi$ out of phase with the process lag, then, conditions which prevent oscillation are brought into effect. The system has now become an oscillator which can be "tuned" to steady oscillation OR DAMPED OUT WITH "DETUNING" BY ADJUSTING THE CONTROL-MECHANISM CONSTANTS. This tuning is accomplished by variation of the constants $P$, $J$, $R$, or returning, positioning, and boosting actions; which is the equivalent of varying the restoring force, damping, and mass of the mechanical system.

### CONCLUSION

If an automatic process control circuit is set up under ideal conditions with adjustable returning, positioning, and boosting actions for the control mechanism, the circuit will follow equations similar to those for a simple forced mechanical oscillating system.

The question arises as to what is the value of considering a process control as a forced oscillator; we are not interested in maintaining oscillations in a system but in preventing them, and in automatic-control work we deal almost entirely with transients as the result of disturbances. The best answer is that in knowing how to treat the process as an oscillator, we know how to prevent oscillations. In mechanical oscillators proper damping can be secured by adjustment of the constants of force, friction, and inertia. Likewise in electrical systems oscillation or degeneration can be attained by adjustments of inductance, resistance, and capacitance. Process controllers should follow the same treatment.

In setting up an ideal control circuit we have had to make a number of assumptions. Those pertaining to the controller are stated in the Introduction. Those pertaining to the process are: First, that there was only one variable disturbance, namely the input temperature, and that input flow and supply temperature were constant. In actual practice an automatic controller will have to cope with a number of variables, but good design of the process will hold these to a minimum. Second, the supply limits with the valve wide open or closed were not considered. Again good design is required to assure that the process operates on the center range of the valve and careful control adjustment then permits operation without running to the valve limits. Finally, the lags were considered sufficient to assure simple harmonic output for a periodic disturbance. In actual practice, if the capacity of the system is small, irregular disturbances will be transmitted without distortion. Operation of the control would not be affected, however, unless the irregularities were extremely great.

While the direct use in automatic process control work of the equations of motion for forced oscillating mechanical or electrical systems imposes limitations on the controlled process, something certainly should be gained in the knowledge of control behavior by such an analogy.

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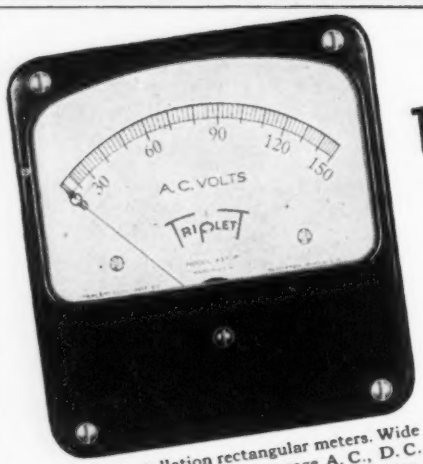


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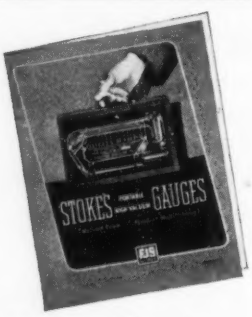


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### Graphical Analysis of Process Transients

*Concluded from page 472*


(8) A. F. Spitzglass. "Quantitative Analysis of Single-capacity Processes." *Transactions A.S.M.E.*, Vol. 60, Nov. 1938, pages 665-674, with 3 figs. Comparison of methods of quantitative analysis of continuous process regulation; fundamental considerations underlying process analysis, and simplifying assumptions necessary for mathematical treatment; equations of the regulator, and their combination with those of the process; bibliography.

(9) E. S. Bristol & J. C. Peters. "Some Fundamental Considerations in the Application of Automatic Control to Continuous Processes." *Transactions A.S.M.E.*, Vol. 60, 1938, pages 641-650, with 14 figs. Fundamental characteristics of continuous processes and automatic controllers, with particular attention to the control of temperature; curves showing the response to sudden load changes; terminology; bibliography.

(10) J. C. Peters. "Experimental Studies of Automatic Control." *Transactions A.S.M.E.*, Vol. 64, April 1942, pages 247-255; with 13 figs. Equipment of the Leeds & Northrup Co., for testing automatic control mechanisms of several models of control; typical results; bibliography, discussions.

(11) H. H. Gorrie. "Selecting Automatic Control Equipment for Continuous Processes." *Instruments*, Vol. 13, April 1940, pages 100-102 (109); with 3 figs. Basic elements of control systems and their classification. Typical control problems. Temperature control: heat storage, transfer lag, transportation lag and controller lag. Pressure and level control: energy storage, controller lag. Draft and flow control.

(12) C. O. Fairchild. "Elementary Theory of Automatic Temperature Control." *Instruments*, Vol. 13, Nov. 1940, pages 334-339, with 4 figs. Derivation of differential equations of heat transfer for the steady state and for the varying state. Bibliography.

(13) Nicholas Minorsky. "Control Problems." *Journal of the Franklin Institute*, Vol. 232, Nov. 1941, pages 451-487 and Dec. 1941, pages 519-551; with 6 figs. Application of operational calculus to linear control problems; general properties of linear systems acted upon by linear controls; stability of controlled systems; non-linear control problems; bibliography.

(14) W. Oppelt. "Vergleichende Betrachtung verschiedener Regelaufgaben hinsichtlich der geeigneten Regelgesetzmaessigkeit" *Luftfahrtforschung*, Vol. 16, No. 8, Aug. 20, 1939, pages 447-472. English Translation: "Comparison of Automatic Control Systems" *N.A.C.A. Technical Memorandum* 996; with supplement. Automatic control of pressure, temperature, speed of rotation, direction; comparison of "faultless" regulator with actual regulators; analysis aids comprehension of the regulating process.

(15) J. G. Ziegler and N. B. Nichols. "Process Lags in Automatic-control Circuits." *Transactions A.S.M.E.*, Vol. 65, No. 5, July 1943, pages 433-444, with 17 figs. Quantitative determination by measuring the area under recovery curves. Term "recovery factor" introduced and values given for various industrial applications. Means for reducing lag. Bibliography. Discussions by numerous workers in the process field.

(16) Kalman J. DeJuhasz. "Graphical Analysis of Transient Phenomena in Linear Flow." *Journal of The Franklin Institute*, Vol. 223, April 1937, pages 463-493; May 1937, pages 643-654; June 1937, pages 751-778; with 36 figs. Concepts and methods of graphic dynamics as applied to flow problems of water hammer and fuel injection; theoretical derivation of formulas; extensive bibliography.

Kalman J. DeJuhasz. "Graphical Analysis of Surges in Mechanical Springs." *Journal of The Franklin Institute*, Vol. 226, Oct. 1938, pages 505-526; Nov. 1938, pages 631-644; with 26 figs.

Kalman J. DeJuhasz. "Graphical Analysis of Free Vibrations in Helical Springs." *Journal of The Franklin Institute*, Vol. 227, May 1939, pages 647-672; with 10 figs. Application of graphic dynamics to spring problems.

Kalman J. DeJuhasz. "Graphical Analysis of Transient Phenomena in Electric Circuits." *Journal of The Franklin Institute*, Vol. 228, Sept. 1939, pages 339-373; with 21 figs. Application of graphic dynamics to electrical surges; closure and opening of circuits with transmission line, capacitance, inductance, and resistance in various combinations.

Kalman J. DeJuhasz. "Graphical Analysis

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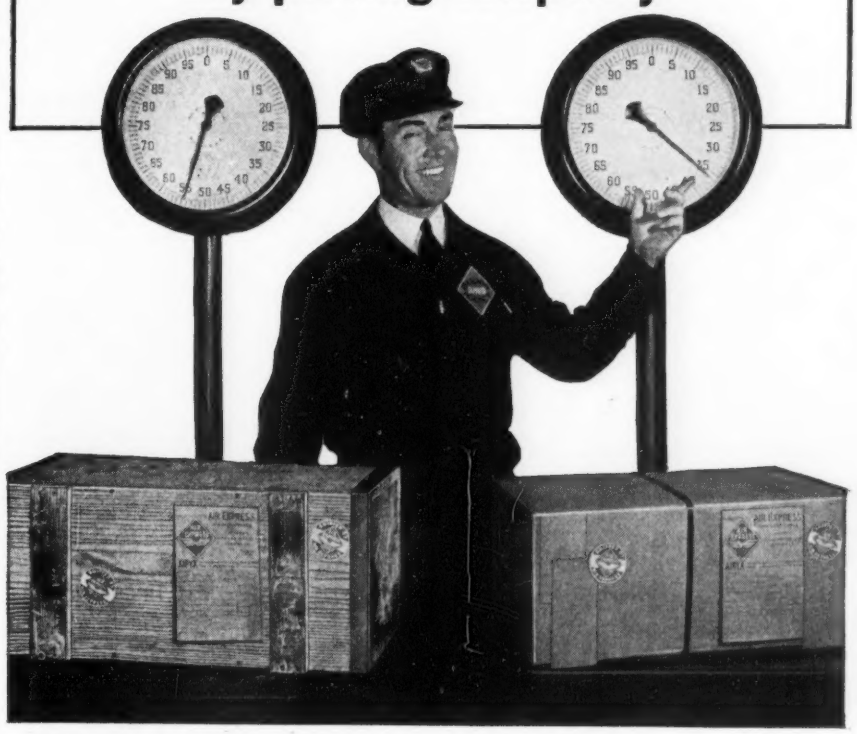

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of Impact of Elastic Bars." *Transactions A.S.M.E., Journal of Applied Mechanics*, Vol. 9. Sept. 1942, pages A-122-A-128; with 14 figs. Application of graphic dynamics to the longitudinal central impact of elastic bars of various lengths, cross sections, elastic properties; state of energy before and after impact.

### Oscillographic Measurements in Spot Welding Research

*Concluded from page 479*

shunt, from sheet-to-sheet and from electrode-to-sheet. Since the shunt with its galvanometer is calibrated in terms of amperes per unit deflection and the other galvanometers are calibrated in terms of volts per unit deflection, instantaneous values of resistance can be calculated by Ohm's law, $R = E/I$.

The potential connections are made in such a way that the sheet-to-sheet resistance, as measured, includes the body resistance of one sheet as shown in Fig. 4. Likewise the electrode-to-sheet resistance includes the body resistance of one-half sheet as shown in the same figure. By keeping each pair of potential connections as nearly as possible in a plane perpendicular to the

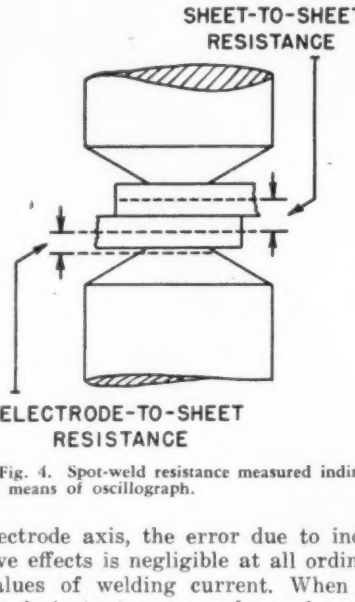


Fig. 4. Spot-weld resistance measured indirectly by means of oscillograph.

electrode axis, the error due to inductive effects is negligible at all ordinary values of welding current. When desired, instantaneous values of power, $P = EI$, can also be calculated from the oscillograms. Some typical sheet-to-sheet resistance characteristics of spot welds in mild steel are shown in Fig. 5. These welds were made with alternating current which was allowed to flow for a time of 6 cycles. At the start of the weld the total resistance was high, consisting of a high contact resistance and a low body resistance. During the first half-cycle of current flow the total resistance decreased very rapidly due to the rapid reduction of the contact resistance. As the current continued to flow, the contact resistance disappeared during the formation of the weld and the body resistance of the metal increased due to its rising temperature.[7] The resistance of the weld made at 14.9 kiloamperes fell off rap-

(7) F. J. Studer, "Contact Resistance in Spot Welding." *Welding Journal*, October 1939, *Research Supplement*, pages 374-380.

idly at the end, due to expulsion of molten metal which was accompanied by a reduction in thickness of the metal between the two electrodes. Similar analyses of oscillographic records have been very useful in determining the relative importance of contact resistance and body resistance in welding other metals, the effectiveness of different surface treatments, etc.[8] Analyses of instantaneous power have shown some interesting effects of high contact resistance at the start of the weld and phase differences with respect to the maximum rate of heat generation at the sheet-to-sheet and electrode-to-sheet contacts.

At this laboratory the cathode-ray type of oscillograph is frequently used to supplement the electromagnetic type. This instrument is most useful for quick tests of the welding and control equipment. It is particularly useful in checking the performance of time and heat control apparatus for a-c. welders,

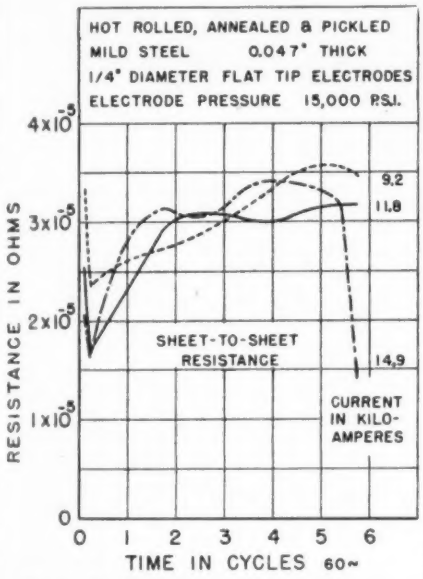


Fig. 5. Typical sheet-to-sheet resistance characteristics of spot welds in mild steel.

in examining the current wave-form in welders of the energy-storage type, and in operating the electric strain gage apparatus for measuring electrode pressure. The most serious limitations of this instrument in its usual form are its inability to record more than one variable at a time and the lack of a single-sweep control which could be synchronized with the operation of a spot-welding machine.

Much of the above material has been presented previously and in greater detail in publications devoted to welding. The author hopes that investigators in other fields may find the present article interesting and useful. For the benefit of those investigators who desire further information, complete references are given.

(8) W. F. Hess, R. A. Wyant and B. L. Averbach, "An Investigation of the Surface Treatment of Alclad 24S-T in Preparation for Spot Welding." *Welding Journal*, June 1942, *Research Supplement*, pages 257-265.

These Frahm Resonant-Reed Tachometers have taken a beating. Designed for permanent mounting, they have been used as portable instruments, continuously for 22 years, on the test floor of a turbine manufacturer. When returned to us for repair and recalibration we found that, except for one reed which had been broken, no reed registered more than 2% out of calibration and nearly all were correct within 1%. The instruments have been repaired and are now back in the same hard service.

Frahm Resonant-Reed Tachometers are simple and rugged in construction . . . accurate and dependable in operation. With no parts to wear, adjust, lubricate or renew they give years of trouble-free service. Built in types for permanent mounting, and for hand use in servicing, testing, installation and maintenance work. Various ranges available from 900 to 30,000 R.P.M.

For a complete description of the Frahm Tachometer together with list of types and ranges commonly supplied, write for Bulletin 1590I.

*The same instruments shown above, after repair and recalibration in the Biddle Repair Department.*

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**Process Control** for sensitive, stable automatic control of temperature, pressure, liquid level, flow and other factors as applied to industrial processes. Responds to changes quickly, without overtravel or hunting. Ask for Bulletin No. 101.

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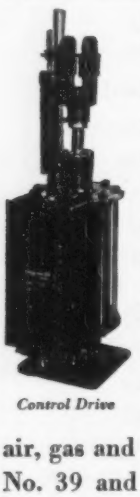
**Boiler Meters** for recording combustion conditions and guiding boiler operators. Described in Bulletin No. 44.

**Multi-Pointer Gages** for indicating factors such as draft, pressure, temperature and speed. These Gages are available with any number of pointers and any scale combination; in either the oil sealed bell or diaphragm construction.



*Control Drive*

**Flow Meters** for indicating, recording and integrating the flow of steam, water, sewage, air, gas and other fluids. Bulletins No. 39 and 300.

**Recorders** for pressure, temperature, drafts, liquid level and other factors.

C-3

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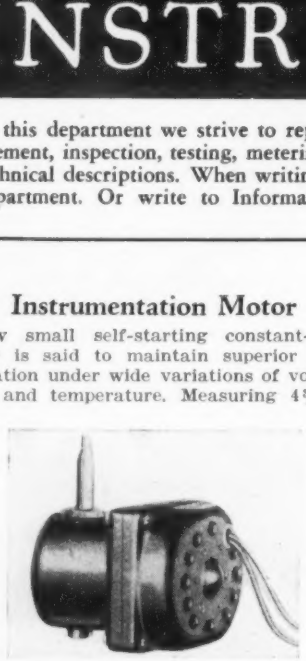
**1041 Ivanhoe Rd., Cleveland, Ohio**

# The Month's NEW INSTRUMENTS

**In this department we strive to report each month ALL the new devices for measurement, inspection, testing, metering and automatic control—in the form of concise technical descriptions. When writing to manufacturers directly, please mention this department. Or write to Information Section, Instruments Publishing Company.**

## Instrumentation Motor

New small self-starting constant-speed motor is said to maintain superior speed regulation under wide variations of voltage, load, and temperature. Measuring 4⅝" × 3⅛" × 3¼", new "Rotom Motor" is available for operation on 110 or 220 volt, 50 or 60 cycle source at 14 watts input. Gears are of helical-cut laminated Bakelite for quiet operation and are completely enclosed and protected. Forced ventilation assures cool operation. Motor is said to have large bearings and ample oil reserves. Shipping weight is said to be "5/2 lbs."—*Rotom Mfg. Co., Alhambra, Calif.*

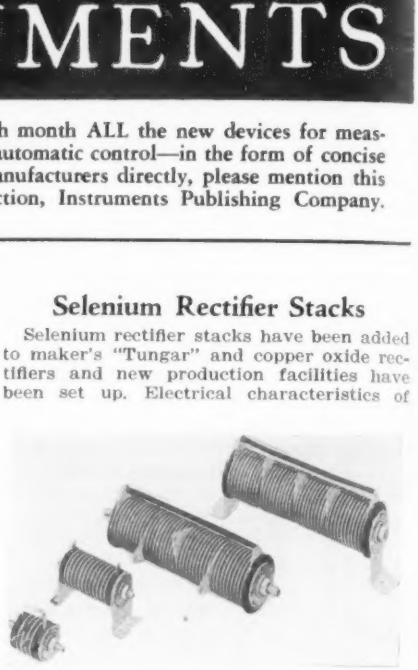


## Ultra-small Oil Capacitors

New "Type 38" ultra-small oil-impregnated oil-filled tubular capacitors for use in assemblies where both space and weight are at absolute minimum, were originally designed as metal-cased alternates for mica capacitors (see illustration) but are now being used for newly-designed equipment. Despite extreme compactness, new units are said to meet many conditions to which the replaced mica capacitors are normally subjected, and to meet all standard specifications for paper dielectric capacitors used as mica alternates. Units are available with both terminals insulated or with one terminal grounded to the case. Pigtail terminals. Normally supplied without outer sleeve but can be had with insulating jacket adding 1/16" to diameter and length. 1" and 1-3/16" long, 5/16" and 7/16" diameters. Castor (Hyvol) or mineral oil impregnant and fill. 300 to 800 v. D.C.W. Capacitances from 0.001 to 0.01 mfd.—*Aerovox Corp., New Bedford, Mass.*

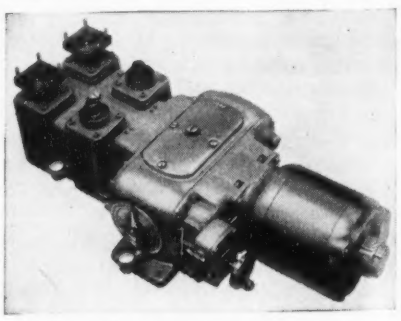
## Selenium Rectifier Stacks

Selenium rectifier stacks have been added to maker's "Tungar" and copper oxide rectifiers and new production facilities have been set up. Electrical characteristics of selenium rectifiers are said to have been greatly improved: better forward current characteristics and extremely low leakage are said to be made possible by a new and patented manufacturing process. As with other types of metallic rectifiers, selenium stacks can be arranged to obtain higher current output by connecting stacks in parallel, and higher voltage ratings by connecting stacks in series. Announcement states that selenium stacks lighter in weight and smaller in overall size than any other type of metallic rectifier. New stacks can be bolt mounted or stud mounted directly to equipment assemblies; are also available with mounting brackets of various types for convenient assembly to panels, etc.—*A & M Dep't, General Electric Co., Bridgeport, Conn.*



## Tachometer Test Drive

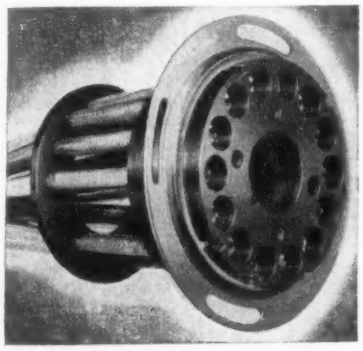
New self-contained variable-speed test drive for testing aircraft tachometers is of fully-enclosed, splash-lubricated, all-metal construction, with ½-h.p. electric motor integrally mounted on one end. It utilizes maker's "V.R.D." speed variator, has an over-all speed ratio of 10 to 1, and is furnished with four vertical drive shafts for mounting of tachometers, or with special swivel head to permit testing in either horizontal or vertical position, as may be desired. The four drives can be supplied all alike or in any desired combination. An interchangeable type of drive can also be furnished. Illustration shows a V.R.D. test unit



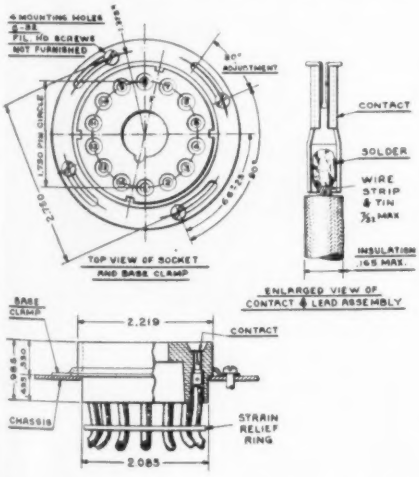
with two types of drives (two of each). Available output shaft speeds are 200 to 2000, 250 to 2500, 300 to 3000 r.p.m., etc. Another feature of unit permits selection of direction of rotation of each shaft: It is possible to operate two tachometers in one direction and two in the opposite direction simultaneously. Infinite speed control can be obtained by turning a hand wheel, requiring 5.84 total turns for 10-to-1 speed range. Hand-wheel-operated vernier control, with a ratio of 7.5:1 or 30:1, can be furnished for more precise speed variation. Dial and pointer indicates speed ratio setting. However, for more accurate requirements a fifth drive can be supplied on gear box. This can be a shaft for connection to stroboscope or strobotron; or it can be a drive of either of two types shown in photograph, for connection to master tachometer. Speed change mechanism employs two pairs of opposed conical disks, between which an all-metal side-contact V.R.D. roller chain transmits the power. On changing speed by turning hand control wheel, this self-adjusting chain rises between one set of disks and descends between the other, so that while the input shaft, connected to motor, turns at constant speed, the speed of four output shafts is adjustable to the desired r.p.m. Speed changes are said to be made easily and smoothly without stopping the drive.—*Link-Belt Co., Philadelphia 40, Penna.*

## Cathode-ray Tube Socket

New one-piece molded construction cathode-ray tube socket was designed to completely enclose and seal the contacts against temperature and humidity conditions. It is

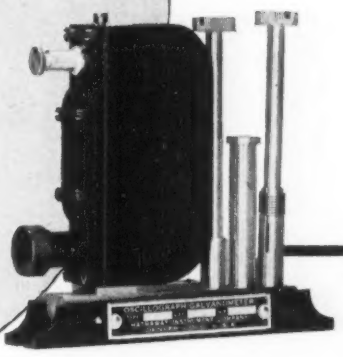


said to provide high voltage flashover at high altitudes and high resistance between adjacent pins. An added feature is its strain relief ring which protects the soldered




joints against vibration pull or twist of the wires. Franklin Cathode-ray Tube Sockets are supplied in either assembled units complete with cable or ready for assembly.—*Franklin Mfg. Co., 175 Varick St., New York City.*


YOUR INSTRUMENT
IS ONLY AS GOOD AS ITS
HEART



HATHAWAY GALVANOMETERS
*(for oscillographs)*

('heart' of a wide variety of recording instruments) have reached such perfection that galvanometers are no longer a limiting factor in the operation of the whole instrument.

Type OA-2, illustrated, is a bifilar galvanometer for applications requiring high-frequency response, low power input, and ability to function under extreme vibration. Its precision optical elements guarantees records of highest quality. Moving element is a single loop of fine metallic ribbon, tightly stretched between the poles of a powerful permanent magnet. Recommended for recording frequencies above 250 cycles. Can be supplied with sensitivity as high as 50 millimeters per milliampere at 1 meter, or natural frequency as high as 10,000 cycles per second! Other types of oscillograph galvanometers are available for higher sensitivities at lower frequencies.

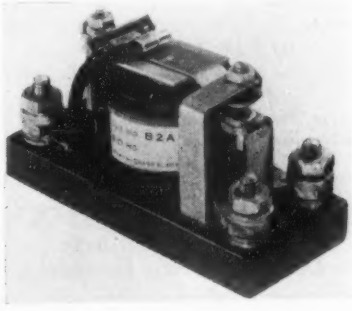
*Write for factual bulletin*

Hathaway INSTRUMENTS

1315 SO. CLARKSON—DENVER, COLO.


## Aircraft Power Relay

New "Bulletin 103" Relay is designed to meet aircraft requirements for a small, sturdy relay, to operate on low d-c. voltage, carry an appreciable load, and perform under vibration, shock and high values of



acceleration. Overall height 1¾", approx. ⅜" of which is taken up by Bakelite molded insulating base which is arranged for two-hole mounting. 3⅛" by 1⅜" base adds rigidly to relay assembly and promotes resistance to vibration and shock. Armature and contact assembly are said to be designed to eliminate possibility of vibration or acceleration dislodging them from either position. In acceleration, relay exceeds 10*G* tests and is good up to vibrations of 60 cycles and 1/32" amplitude. Husky terminal inserts, firmly molded in base, with a generous amount of running thread, facilitate front connections. Relay coil is paper layer wound and impregnated to assure protection against climatic conditions. Normally-open s-p.s-t. contacts are rated 25 amps. at 24 volts d.c. non-inductive load, with good characteristics on inductive loads. Contact gap and tail spring tension are adjustable. —*Ward Leonard Electric Co., Mount Vernon, N. Y.*

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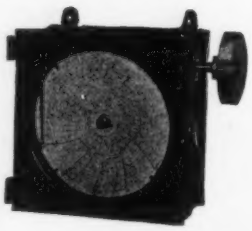

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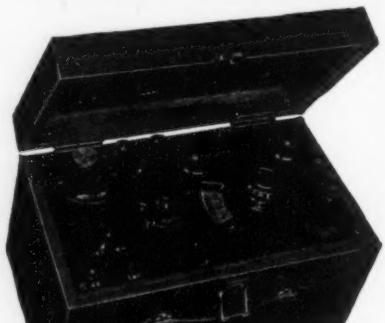

Available in a number of double-range combinations, such as 1 volt and .1 volt, 100 MV and 10 MV, also in pH ranges. Guaranteed accuracy .1%. *An outstanding value.*

Described in Bulletin 270 which also describes *Rubicon* High Precision Type B Laboratory Potentiometer.

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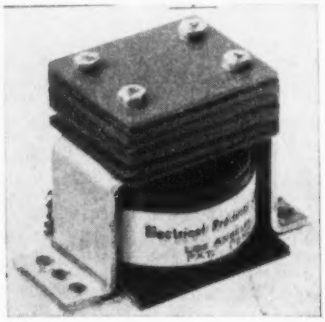
## "Sealed-chamber" Midget Relay

One of safety features of new midget relay is a "sealed" chamber which serves as effective arc quench and effectively reduces fire and explosion hazards, it is said. While



rated at 25 amps., new relay operates satisfactorily at 50 amps. and has tested without failure at 120 amps. high inductive load, it is said. Overtravel spring insures positive contact pressure and instant "break" release. It is tamper-proof because factory adjusted and sealed. Another feature is that contacts, if worn with excessive use, may be reversed in the field, providing new surfaces without disturbing adjustment. New relay unit has withstood Army tests including: overload; vibration 55 cycles per second with 0.06" excursion; acceleration of 10*G*; 200-hour salt spray.—*Electrical Products Corp., 1322 S. Grand Ave., Los Angeles, Calif.*

## Production Hardness Tester

New hardness tester for Rockwell testing is announced in three models, "US8," "US12" and "US16"; is said to embody a number of features contributing to accuracy

of measurement and speed of operation. Among these are a frictionless spindle which provides a correct minor load at all times; "Zero Drag Trip" said to eliminate friction or drag on loading beam and assure consistent accuracy of the major load; a dial indicator adjustment affording a convenient; simple means of maintaining accuracy of readings; and a minor load adjustment. Other features: fully-enclosed elevating screw with self-lubricating oil reservoir, and an adjustable steady rest. Instrument is supplied complete with diamond cone pene-

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**1**—Accuracy .0002, .0003, .0004, .0005.

**2**—Checked carefully with optical instrument.

**3**—Hard surface. Wear shown as scratches. These do not affect accuracy unless grouped densely. Scratches do not burr.

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**5**—Requires no de-magnetizing.

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**7**—Transparent. Data or formulae may be placed under the flat for ready reference.

**8**—Easy to check. Optical instruments for checking purposes available in most large centers.

**9**—Replaces critical material.

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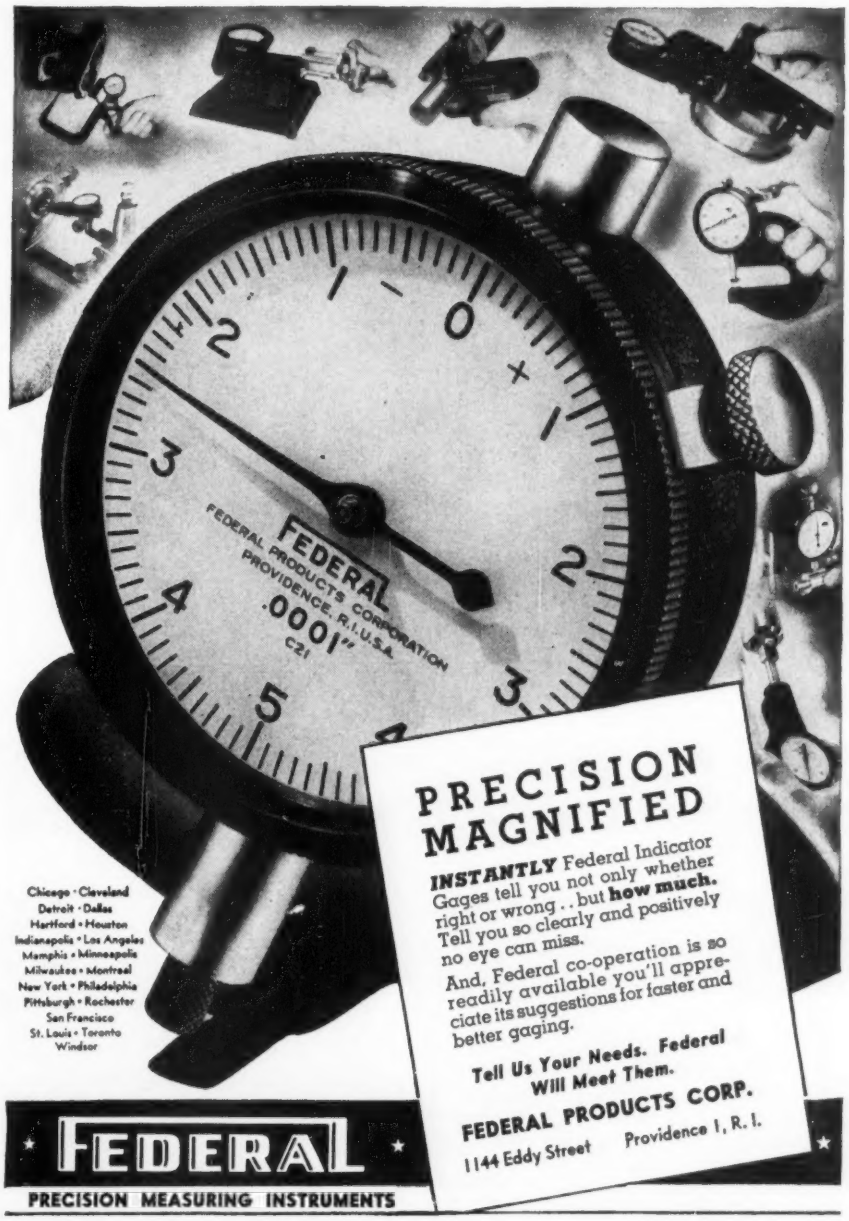
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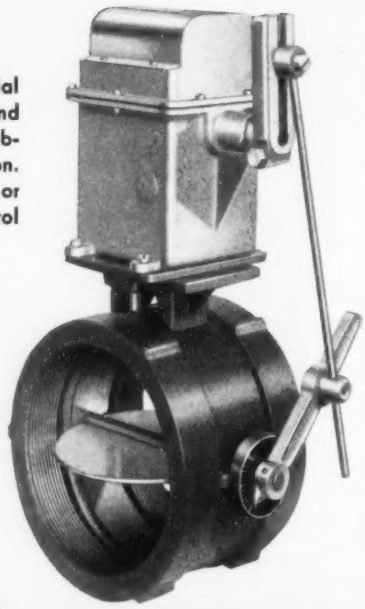
These POWER UNITS are ideally suited for industrial applications. They feature built-in limit switches and a high torque motor with gear reduction, oil submerged, for long life and dependable operation. Control action may be governed by a recording or indicating controller or other contact making control instruments. POWER UNITS are available for "on-off", floating, and proportioning modes of control, including proportioning with manual or automatic resetting.



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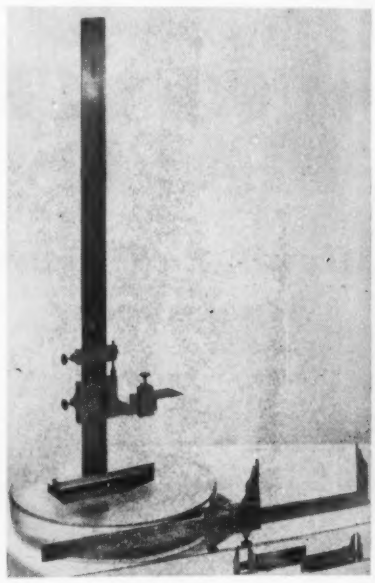
trator and steel ball penetrators for Rockwell testing on "C" scale, "B" scale and most other standard Rockwell scales. Three anvils are included: a standard 3½" anvil for large flat bearing surface work; a spot anvil for most standard size pieces and for use with test blocks; and a vee anvil for testing round and cylindrical parts. These are in addition to the two smaller vee anvils that form part of the adjustable steady rest. —*Clark Instrument, Inc., 10300 Ford Road, Dearborn, Mich.*

### Vernier Height Gages

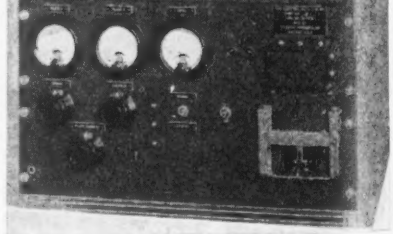
Latest addition to maker's line of precision tools is an 18" Vernier Height Gage. This gage has all working surfaces lapped to 5 wave-lengths of flat. It is also manufactured



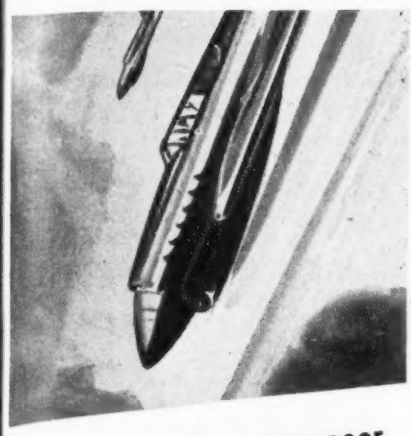
in 10", 24" and 36" sizes. Company also announces that it manufacturers Glass Surface Plates in four sizes, optically ground to within five wave-lengths of flat. Glass in these surface plates has a low coefficient of expansion and a high stability of shape. —*The McGrath St. Paul Co., St. Paul, Minn.*

### Balanced Relay Test Panel

New "Model 81" Balanced Relay Test Panel is for testing aircraft and industrial relays in production. No wires or external connection clips are needed; just insert re-



lay on carriage which moves up and down. Carriage can be arranged to take almost any type of commercial relays and, when fitted, motion of lever is directed upward into contact box which effectively shields operator from connection to high voltage at all times. Circuit is said to be arranged to duplicate actual field conditions by virtue of complete variable control of field current so that a complete and universal test may



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**Small, compact and lightweight**

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For example, take this hermetically-sealed unit designed by the N-Y-T Sample Department. While it weighs only five ounces and measures but 1⅜" in diameter by 1¾" high, it is both immersion proof and shock-proof. The moisture pouring off an icy transformer, which has just dived from a sub-zero temperature in the stratosphere to a few thousand feet above a steaming tropical zone, may well be imagined. Protection must be assured in all phases of modern warfare; equally important to functional efficiency and accuracy are size and weight.

This is but one of the innumerable solutions for vital Army, Navy and Air Corps requirements achieved by N-Y-T. Unceasing research and testing are embodied in every transformer problem by our engineers.

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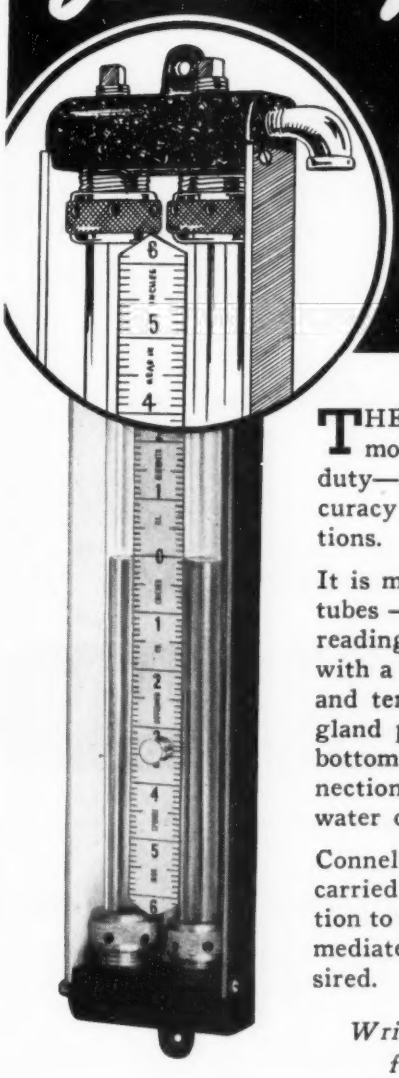
# Connelly EXTRA HEAVY DUTY Manometers

FOR PERMANENT MOUNTING



THE New Connelly Manometer, model 3400—built for extra heavy duty—can be depended upon for accuracy and long life under all conditions.

It is made with large bore, clear glass tubes — ¾" in diameter — for easier reading even at a distance. Supplied with a scale graduated either in inches and tenths or in metric measure. It is gland packed, with drain plugs at the bottom and is fitted for ⅛" pipe connections. Made for use with either water or special anti-freeze solution.

Connelly Model 3400 Manometers are carried in stock in five sizes. In addition to these stock sizes, larger or intermediate sizes can be supplied if desired.

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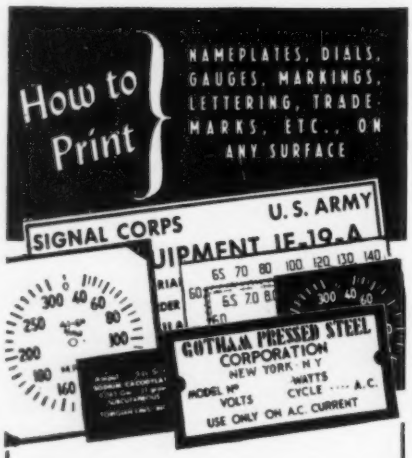
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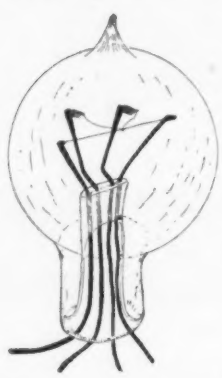

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Higher current ranges in air.

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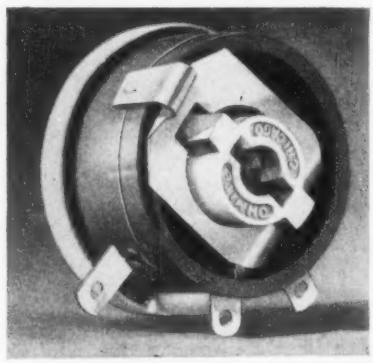
easily be made. Instrument is said to be especially useful for balanced relays where current through each coil must be identical. It is possible by means of a balance control to upset or create a balanced condition. Instrument comes complete and ready to operate mounted on standard relay rack panels; a spare panel at top of cabinet for additional switching or indicating accessories user may find convenient. External power supplies are used. Instrument is 20" wide, 15" high, 14" deep, weighs 16 lbs. Standard Type 301 Weston instruments are used. — *Televiso Products, Inc., 6533 No. Olmsted Ave., Chicago, Ill.*

## Circular Slide-wire Rheostat

New circular slide-wire rheostat is designed especially for low-resistance low-wattage applications in the instrument field. A length of resistance wire is stretched



tightly around a cylindrical core bonded to a ceramic base. Wire is firmly anchored to two terminals; contact to wire is made by a phosphor-bronze spring arm connected to a third terminal. Provision of three terminals allows unit to be used as a voltage divider. Maximum resistance which can be supplied on this unit is approx. 1 ohm; minimum total resistance can be made approx. 0.1 ohm. Since contact arm travels along the wire from end to end, resistance variation is stepless. Shafts for knob control or for screw driver control can be supplied. These units are made to order to suit the particular application.—*Ohmite Mfg. Co., 4835 West Flournoy St., Chicago 44, Ill.*

## Propeller Governor Test Stand

New propeller governor test stand is for checking Hamilton Standard double-acting, accumulator, hydromatic and constant-speed and Curtiss Proportional and lubricated pad type governors. Measuring 60" × 36" × 36", it has a welded steel framework covered by a detachable metal jacket for ease in servicing the bench itself. Minor re-

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## LITTLE Changes Can Make A BIG Difference

But the important thing is—where and how changes in the design of permanent magnets should be made. That takes knowledge of the subject of magnetism.

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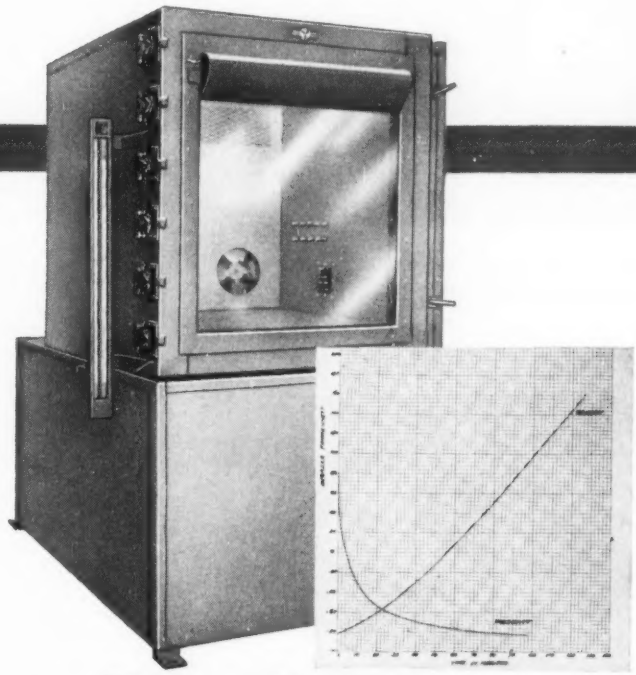
Only *Mobile* units offer program controlled or manually set flight-similitude conditions. These units provide completely coordinated altitude-temperature curves to a maximum of 80,000 feet altitude at a temperature minimum of — 120° F.

Reheat and humidity testing is standard also in these *Mobile* units, up to +185° F with fully controlled humidity conditions according to your requirements. Our production time has recently been cut by almost 40%. We invite your inquiry.



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pairs may be made by removing front and rear panels. Storage drawer in front of bench is used for adapters, hoses and connectors. Governor to be tested is mounted vertically by means of quick-adjusting clamps and its proper alignment is assured through two steel dowels that hold it in place. Circular mounting pad is surrounded by a sump which drains all leakage back through a filter to the oil reservoir. Bench incorporates complete hydraulic system for testing Hamilton Governors. Main oil reservoir holds 14 gals. of oil—more than twice the per-minute pumping of any governor. To duplicate temperature of oil which governor would receive from a plane motor, a heating unit is installed in tank where SAE No. 50 oil is thermostatically held at 160°F. Two lamps on instrument panel indicate proper temperature for testing. Viscosity should be at 200-300 Saybolt Universal seconds. A vacuum gage warns bench operator if oil line clogs. Test stand has control switches at bottom of instrument panel within easy reach of operator for testing electrical devices. Operator tests for minimum and maximum r.p.m., for capacity, recovery, pressure, external and internal leakage and feathering.—*Airplane Mfg. & Supply Corp., 6353 Lankershim Blvd., North Hollywood, Calif.*

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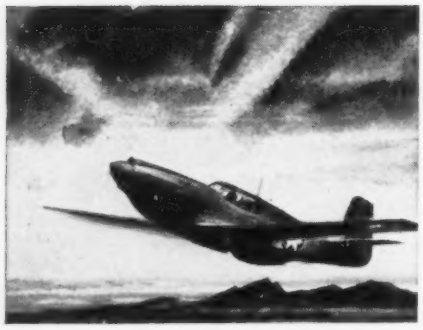
### Locking Ring

New locking ring is for locking sockets and components to chassis and bases. It is claimed that with it, "millions of labor hours can be saved, a positive lock assured and unlocking doesn't damage either the



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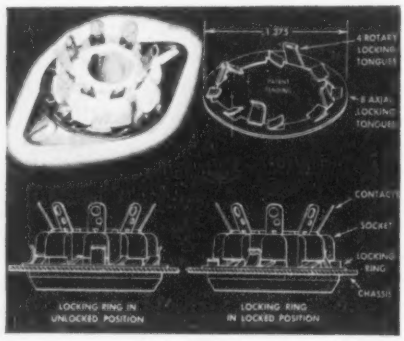
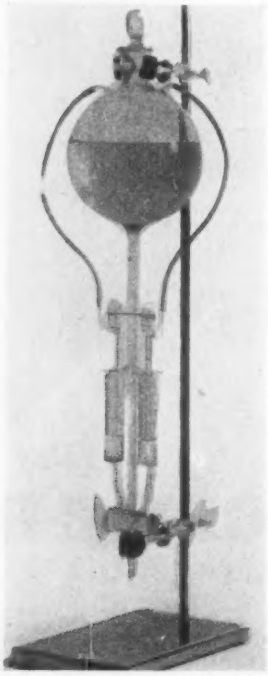
component or the chassis." Its operation is simple and uninvolved: it fits between chassis and the component to be locked; a simple tool is placed over component and a ⅛ turn to the right securely locks component to chassis; a further ⅛ turn does




the unlocking. While this locking ring was developed for the electronic and radio industries it can be applied wherever parts are locked to parent bodies.—*A. W. Franklin Mfg. Co., 175 Varick St., New York, N. Y.*

## Adjustable Automatic Pipette

New "Twin Adjustomat" adjustable automatic pipette is said to be a precision instrument equally adaptable to analytical procedures and to operations requiring ac-



curate measurement of liquids, as in filling ampoules, vials, bottles, etc., and in tubing media for microbiological assay of vitamins, in running phenol coefficients, in water analysis, etc. A rapid simple adjustment enables it to deliver any desired volume of liquid with an accuracy of 0.1 ml. Not being limited to the delivery of a single fixed volume, it speeds up filling ampoules, vials and bottles to as many as 1,500 units per hour. Man-hours may be saved by its use also in laboratories. It may be sterilized for procedures requiring aseptic technique. Standard instrument has a reservoir capacity of 2,000 ml. Delivered volume adjustable from 1 to 50 cc. Special sizes available on request.—*Horton & Converse, 621 West Pico Blvd., Los Angeles, Calif.*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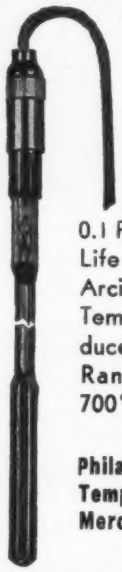
**Philadelphia Merc-to-Merc Thermo-Regulators Feature**



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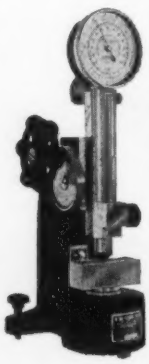

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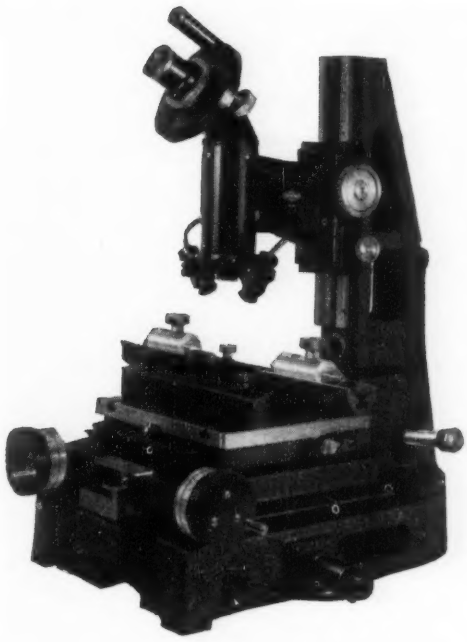

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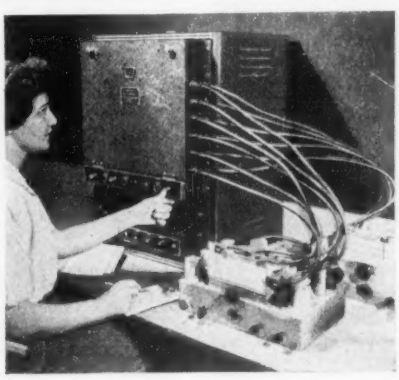
## High-speed Circuit Tester

New "Rotobridge" is an automatic high-speed mass production tester of interest to test and production engineers faced with necessity of using unskilled labor for factory circuit checking. Instrument is said to make it possible to "attain Wheatstone bridge precision while testing circuits at the amazing rate of one circuit per second." It requires only one set up; is used for testing all types of communication, electronic and electrical equipment for errors in resistance, reactance, and in circuit wiring. Since human element is almost completely eliminated, specified tolerances are absolutely maintained, it is said. Makers announce also another model for companies producing aircraft, tanks, switchboards, etc.: its use enables rapid testing of multi-wire cable harnesses: up to 120 circuits (including several hundred wires) may be tested at once, in 4-minutes operating time.—*Communication Measurements Laboratory, 116 Greenwich St., New York City.*



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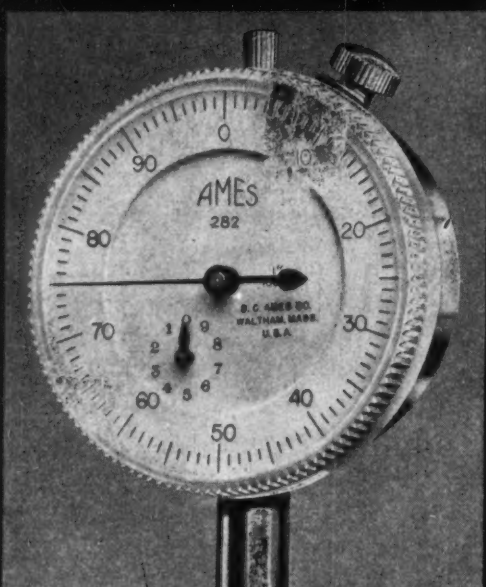


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# Instrument Society News

## ATLANTA

Although, in accordance with the by-laws, the Georgia Society for Measurement and Control holds no regular meetings in July and August, luncheon meetings are held in these months. The first was held July 26 at the Imperial Hotel Coffee Shop. There was nothing formal—just a get-together and impromptu technical discussions.

## NEWARK

### ANNOUNCEMENT OF OCTOBER MEETING

The October meeting of the New Jersey Society for Measurement and Control will be held at the Public Service Terminal Restaurant on October 5. Dinner at 7, meeting at 8. Mr. C. B. Moore, Pres., Moore Products Co., Philadelphia, will speak on "Applications of the Null Principle."

## PHILADELPHIA

### ANNOUNCEMENT OF THE SEPTEMBER MEETING

The September meeting of the Philadelphia Society for Instrumentation will be held at the Engineers' Club, 1317 Spruce St., on September 6. Dinner at 6:30, meeting at 8. Mr. Walter Wills, Brown Instrument Co., will speak on "Continuous Temperature Measurement with Electronic Potentiometers."

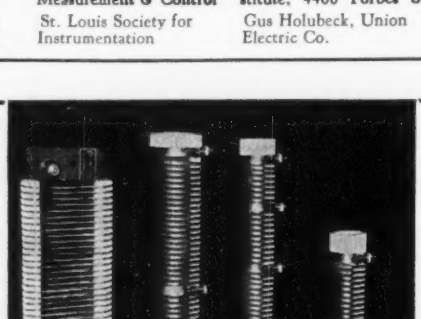
## SAINT LOUIS

*Instruments* has received a belated notice of the organization of an instrument society in St. Louis last spring. Following is a list of the Charter Members, who constitute also the Executive Committee: *Chairman*, H. Bruce Greaves, Monsanto Chem.; *Vice Ch.*, Phil Watson, Curtiss-Wright; *Treas.*, John Posgay, Aluminum Ore Co.; *Sec'y*, Gus Holubeck, Union Electric; *other Committeemen:* Harold Brockmeier, Western Cartridge Co.; Paul Hoyt, Shell Petroleum; John Huck, Jr., Granite City Steel Co.; E. B. Miller, Foxboro Co.; Harry Weeks, Weeks Engrg. Co.; Stanley Wright, Owens-Illinois Glass Co.

## DIRECTORY

City, Society and Secretary

| | | |
|---|---|---|
| **Atlanta** | Georgia Society for Measurement & Control | D. D. Beach, P.O. Box 4569, Atlanta, Ga. |
| **Baltimore** | Baltimore Industrial Instrumentation Society | Fred Pullen, Bethlehem Steel Co., Sparrows Point, Md. |
| **Chicago** | Chicago Society for Measurement & Control | Carl Hope, 2626 W. 31st Blvd., Chicago |
| **Hartford** | Hartford Society for Measurement & Control | Stephen J. Zelle, Whitney Chain & Mfg. Co., Hartford, Conn. |
| **Newark** | New Jersey Society for Measurement & Control | R. F. Robey, 409 Orange Ave., Cranford, N. J. |
| **New York** | New York Society for Measurement & Control | R. K. Farnham, 545 Fifth Ave., N. Y. C. |
| **N. Indiana** | Northern Indiana Soc. Measurement & Control | R. W. Schreiner, 4 Waltham St., Calumet City, Ill. |
| **Philadelphia** | Philadelphia Society for Instrumentation | George Hammer, 712 Otis Bldg., Phila., Pa. |
| **Pittsburgh** | American Society for Measurement & Control | L. M. Susany, c/o Carnegie Institute, 4400 Forbes St., Pgh. |
| **St. Louis** | St. Louis Society for Instrumentation | Gus Holubeck, Union Electric Co. |



TUBULAR RESISTORS
PROTECTED and UNPROTECTED
SLIDE-CONTACT RHEOSTATS
**Rex Rheostat Co.** BALDWIN, L. I., N. Y.

# Manufacturers' New Literature

**In this department we report ALL pieces of new literature pertaining to Instrumentation, received from the manufacturers. To assist in the War Effort we urge readers to request ONLY those bulletins which will be of value to them. Use the coupon on this page.**

K-235 **Inkless Recorders.** Bulletin GEA-3187C, 8" × 10½", 12 pages, describes portable inkless strip-chart recorders: voltmeters, ammeters, millivoltmeters, milliammeters, microammeters, survey instruments with 1 inch-per-day-chart speed. General Electric Co., Schenectady, N. Y.

K-236 **Pneumatic Differential Pressure Transmitter.** Bulletin No. 43-4, 8½" × 11", 8 pages, describes a new transmitter offered to measure flow and level, which operates on the force-balance principle, like a weigh scale, the value weighed by the transmitter being the force of the differential pressure on a measuring diaphragm. Hysteresis loop is less than 0.05%. Full flow change registers in 15 seconds with 500 ft. of ¼ in. O.D. tubing. Republic Flow Meters Co., 2240 Diversey Parkway, Chicago, Ill.

K-237 **Rotameters.** Catalog Sections 981-Y and 99-Z forming one 22-page 8½" × 11" brochure. The new two-section catalog entitled "The Theory of the Rotameter" and "Rotameter Capacities and Correction Factors." It includes a thorough discussion about the history and development of area-type flow meters. One subject, in particular, called "Analysis of Accuracy of Rotameters" is approached from a new and unusual viewpoint that will be of interest to all engineers with flow rate problems. Fischer & Porter Co., 936 County Line Rd., Hatboro, Pa.

K-238 **Electrical Connectors, Fittings, Low-Loss Transmission Cables.** Catalog 70, 8½" × 11", loose leaf folder, 160 pages, lists connectors primarily designed for use in army and navy aircraft but which are also extensively used on tanks, ships, anti-aircraft equipment, firing control devices, radio equipment, etc. Send requests for this catalog direct to American Phenolic Corp., 1830 S. 54 Ave., Chicago, Ill.

K-239 **Cathode-Ray Tubes and Instruments.** Flexible binder, 120 pages, 8½" × 11", entitled "Reference Manual Cathode-Ray Tubes and Instruments, first edition, 1943, describes products of Du Mont manufacture. As this manual is no doubt an expensive piece of literature, requests for it should be made direct to Allen B. Du Mont Labs., Inc., Passaic, N. J.

K-240 **Instruments Rental List.** Spiral binding, 8½" × 11", 38 pages, presents a list of instruments and machines which describes the instruments made available on a rental basis by Waugh Laboratories, 420 Lexington Ave., New York, N. Y. The list covers instruments for the measurement of vibration, sound, strain, time, space and movement, etc.

K-241 **Vibration and Sound.** The June issue of the General Radio Experimenter contains Part IX of the Noise Primer, the measurement of vibration and sound. General Radio Co., 30 State St., Cambridge A, Mass.

K-242 **Pyrometer Control of Salt Baths.** Bulletin HT-S-2, 8½" × 11", 6 pages, describes the use of the radiomatic pyrometer with a sillimanite target tube for controlling the temperature of high-speed salt baths. Brown Instrument Co., Wayne and Roberts Aves., Philadelphia, Pa.

K-243 **Recording Thermometers.** Bulletin T-800, 8½" × 11", 40 pages, describes the various models and styles of thermometers for recording temperatures between −125° and +1000° F. considerable space is given to basic theory of the several types offered, as well as practical information regarding ranges, charts, bulbs, and tubing materials. Bristol Co., Waterbury, Conn.

K-244 **Hydraulic Control.** Bulletin 78-D, 8½" × 11", 8 pages, describes the exactor hydraulic control, for operation of industrial, marine and aircraft equipment—a single-tube, remote-control system; capacity up to 400 inch-pounds; motion through 55° without time lag or backlash. Sperry Products, Inc., Hoboken, N. J.

K-245 **Ohm's Law and Parallel Resistor Charts,** 26" × 36" each. The **Ohm's Law Chart** is used for graphical determination of wattage, voltage, current and resistance. The **Parallel Resistor Chart** is used for graphical determination of the resistance of resistors in parallel. Explanatory examples are given onthe face of each chart. The two wall charts are available without charge to schools, training centers, engineers, procurement officers and plant executives who write for it on official stationery or company letterhead. Ohmite Manufacturing Co., 4835 Flournoy St., Chicago (44), Ill.

K-246 **Timers, Relays, Switches.** Condensed catalog I, 4" × 9¼", 24 pages, describes the function of the many different types of timers and also mentions for just what applications the particular timers are generally used and it gives the reader a greater understanding of the type of timer that would suit the application he has in mind. R. W. Cramer Co., Inc., Centerbrook, Conn.

K-247 **Automatic Valve Operators.** Catalog A4, 8½" × 11", 4 pages, describes a mechanism designed for industrial operation of valves, dampers, or other control devices between two adjustable positions for regulation of temperature, pressure, flow or level. Profusely illustrated with photographs and drawings, the literature covers essential engineering information, design features and operating data. Valves, commonly mounted to this unit, are illustrated; and, tabular data are given on dimensions and operating force. Electrical data and force-torque information are shown in easily read tables to assist in the speedy selection of the proper control mechanism. Automatic Temperature Control Co., Inc., 34 East Logan St., Philadelphia, Pa.

K-248 **Insulation Tester.** Bulletin 1730, 9" × 12", 4 pages, illustrates the first **U. S.-made** "Megger" housed in a molded case of high impact-strength plastic material. James G. Biddle Co., 1211 Arch St., Philadelphia, Pa.

K-249 **Radio-Noise Filter.** Bulletin GEA-4098, 8" × 10½", 8 pages, describes a new filter for aircraft applications. Operation of filter, performance, attenuation characteristics and application are covered. General Electric Co., Schenectady, N. Y.

K-250 **Micropositioner.** Data sheet AP-30, 8½" × 11", 1 page, describes a polarized direct current voltage sensitive relay built for aircraft applications. It is used for remote positioning of control motors, in the control of air valves, engine cowling flaps, trim tabs, etc. Barber-Colman Co., Rockford, Ill.

K-251 **Handling Multiple-Point Charts.** Folder, 8" × 10½", 6 pages, illustrates a method for handling and comparing strip chart records using a daily tear-off device. Leeds & Northrup Co., 4955 Stenton Ave., Philadelphia, Pa.

K-252 **Engraver.** Catalog 250, 6" × 9", 12 pages, describes a pantograph machine adaptable to many lettering tasks associated with experimental work as well as the routine production of panels, nameplates and small parts. Mico Instrument Co., 80 Trowbridge St., Cambridge, Mass.

K-253 **Vacuum Tubes.** The June issue of the C-D Capacitor has a lead-off article entitled "Army-Navy Preferred List of Vacuum Tubes," covering the unclassified general purpose tubes selected jointly by Army and Navy. Cornell Dubilier Electric Corp., South Plainfield, N. J.

K-254 **Optical Comparators.** Form 42-211, 8½" × 11", 22 pages, describes two models of optical projection machines which can be used to check the dimensions of various manufactured parts. Jones & Lamson Machine Co., Springfield, Vt.

K-255 **Mechanical Star Gage.** Looseleaf folder, 8½" × 11", 16 pages, contains descriptions and specifications for mechanical star gages. Illustrations show application to checking 75 mm gun barrel. Pratt & Whitney, West Hartford, Conn.

K-256 **Vibration Fatigue Testing Equipment.** Catalog F, 8½" × 11", 10 pages, describes three vibration fatigue testing machines for testing parts and assemblies setting up essentially the fatigue and stresses set up when similar members are placed in service. All American Tool & Mfg. Co., 1014 Fullerton Ave., Chicago, Ill.

K-257 **Testing Machines.** Bulletin 161, 8½" × 11", 40 pages, describes the Southwark-Ttate-Emery universal testing machines, capacities from 60,000 to 400,000 lbs. Special features of these machines are described. Balwin Southwark Div., Nicetown, Philadelphia, Pa.

**TO PREVENT WASTE AND AID WAR WORK**

**(1) Request only the literature that will aid you. (2) Paste the coupon on a government postal card addressed to *Instruments*, taking care to make all four edges stick.**

*Instruments,* 1117 Wolfendale St., Pittsburgh, Pa. (AUG. 1943)

**Please have the following catalogs, etc., reviewed in this issue sent to me.**

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I also desire further information concerning the following new products described in this month's "New Instruments" Department.....

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An adjustable timing relay operating without clockwork or motor.

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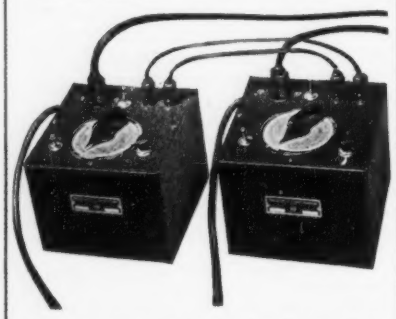

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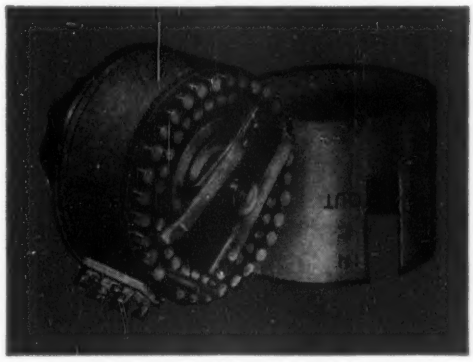
## You've been sleeping a long time, Rip—

Today's dizzy pace must seem frightfully strange to you. Don't feel too badly about it though, because a lot of us are looking at it with similarly unbelieving eyes.

We were awakened from *our* peaceful sleep by some big-time heels who decided they were a master race, destined to lord it over an enslaved world. We were to be the slaves.

Now look at this factory. It's one of the many thousands in this country alone, that are designing and building tools required to win the most shameful and bloodiest of all wars.

Come on, Rip, snap out of it. We're all needed. Our specific job is to continue producing the most complete line of precision attenuators in the world. There's a war job for you, too.



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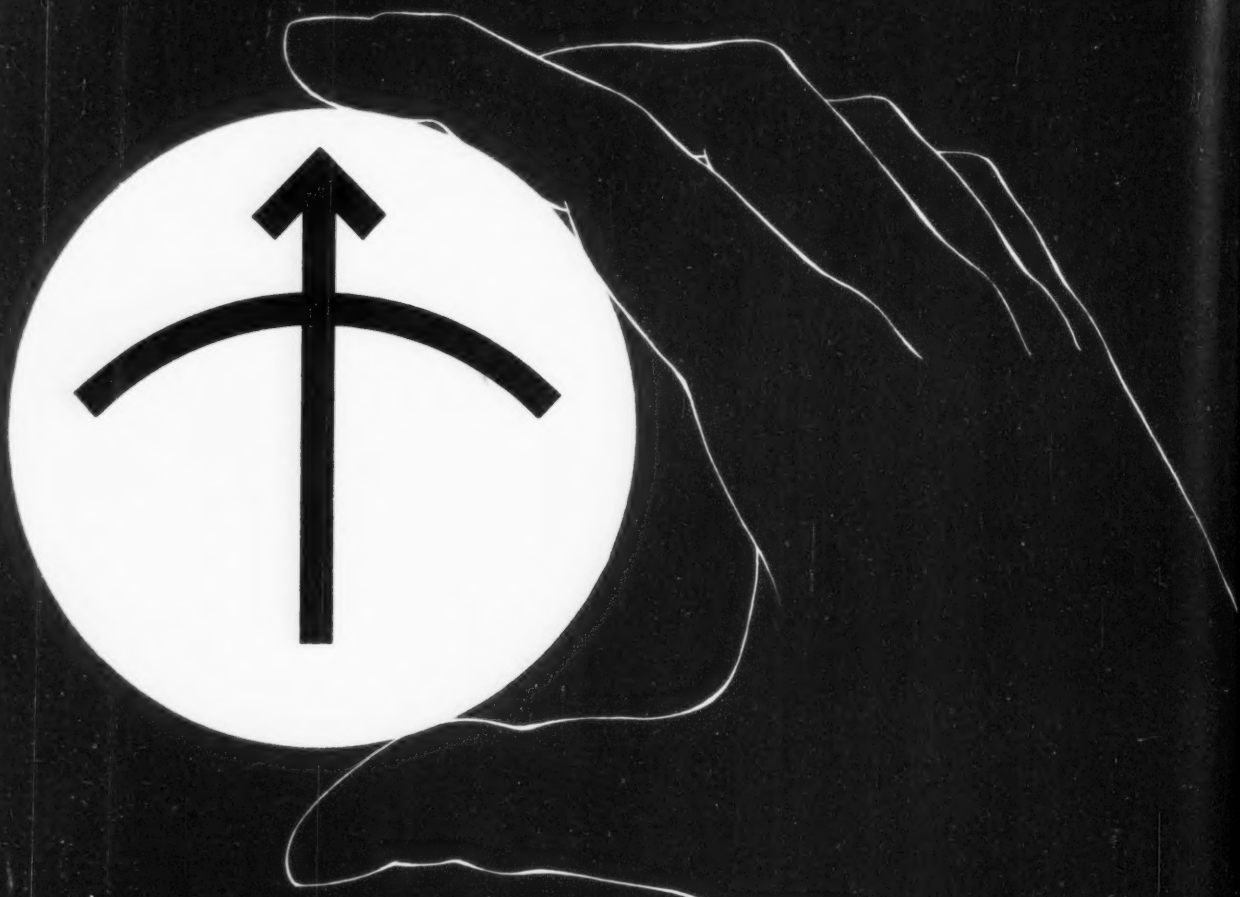

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